Scottish Sanitary Survey Project

Sanitary Survey Report

Loch Striven

AB 205

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Cefas

FOOD STANDARDS AGENCY SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Loch Striven

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* Distribution of both draft and final reports to relevant agency personnel is undertaken by FSAS.

** Distribution of draft and final reports to harvesters in undertaken by the relevant local authority.

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1. General Description

Loch Striven is located on the southwest coast of Scotland and is fairly sheltered by surrounding islands and mainland. It has a north-south aspect and is roughly 13.5 km in length and 1.3 km at its widest point. The bottom shelves steeply away from the shoreline to a maximum depth of 69 metres.

Figure 1.1 Location of Loch Striven

2. Fishery

Loch Striven production area is comprised of two commercial common mussel (*Mytilus edulis*) sites at Troustan and Fearna. Additionally there is a small Pacific oyster culture site that is not currently in commercial production.

Table 2.1 Loch Striven classified sites

Production Area	Site	SIN	Species
Loch Striven	Loch Striven	AB 205 062	Common Mussels
Loch Striven	Troustan	AB 205 063	Common Mussels

The current production area boundaries are listed as the area bounded by lines drawn between NS 0493 8280 and NS 0541 8280 and between NS 0761 7550 and NS 0900 7550. The RMP for the production area is currently located at NS 072 772. There are three seabed lease areas within the Loch Striven production area, which relate to three sites (Troustan, Fearna and Loch Striven).

The Troustan site lies along the western shore of the loch, toward the southern end of the current production area. The Fearna site lies along the eastern shore approximately 2 km north of Troustan. Both sites have longlines with a system of continuous rope ladders strung in loops to a depth of 8 metres along the long lines. As a consequence, the exact depth at which mussel samples are taken from is difficult to estimate at these sites compared to other sites where vertical downlines are used. Harvest is rotational within the sites and 10 of the long lines are typically harvested from each site each year. Both sites are under the same ownership.

Currently, Fearna has two blocks consisting of 10 long lines each, with a third block due to be deployed in the near future. Troustan has 3 blocks of 10 long lines each. Harvesting typically takes place between November and May. No harvesting is undertaken between July and November due to environmental and market factors.

A further lease area (the Loch Striven site) is located at the northern end of the production area at which bags of Pacific oysters were suspended below a raft. Stock of a harvetable size was present on this site at the time of shoreline survey. Although this site has formerly been classified for the harvest of Pacific oysters, the harvester indicated that they are not intended for commercial sale. As no classification is required for this species, no monitoring recommendations will be made in this report. Any information about this site pertinent to the overall assessment, such as historical *E. coli* monitoring data, will however be presented.

Figure 2.1 shows the relative positions of the fisheries, the current Loch Striven production area, the seabed leases and the RMP.

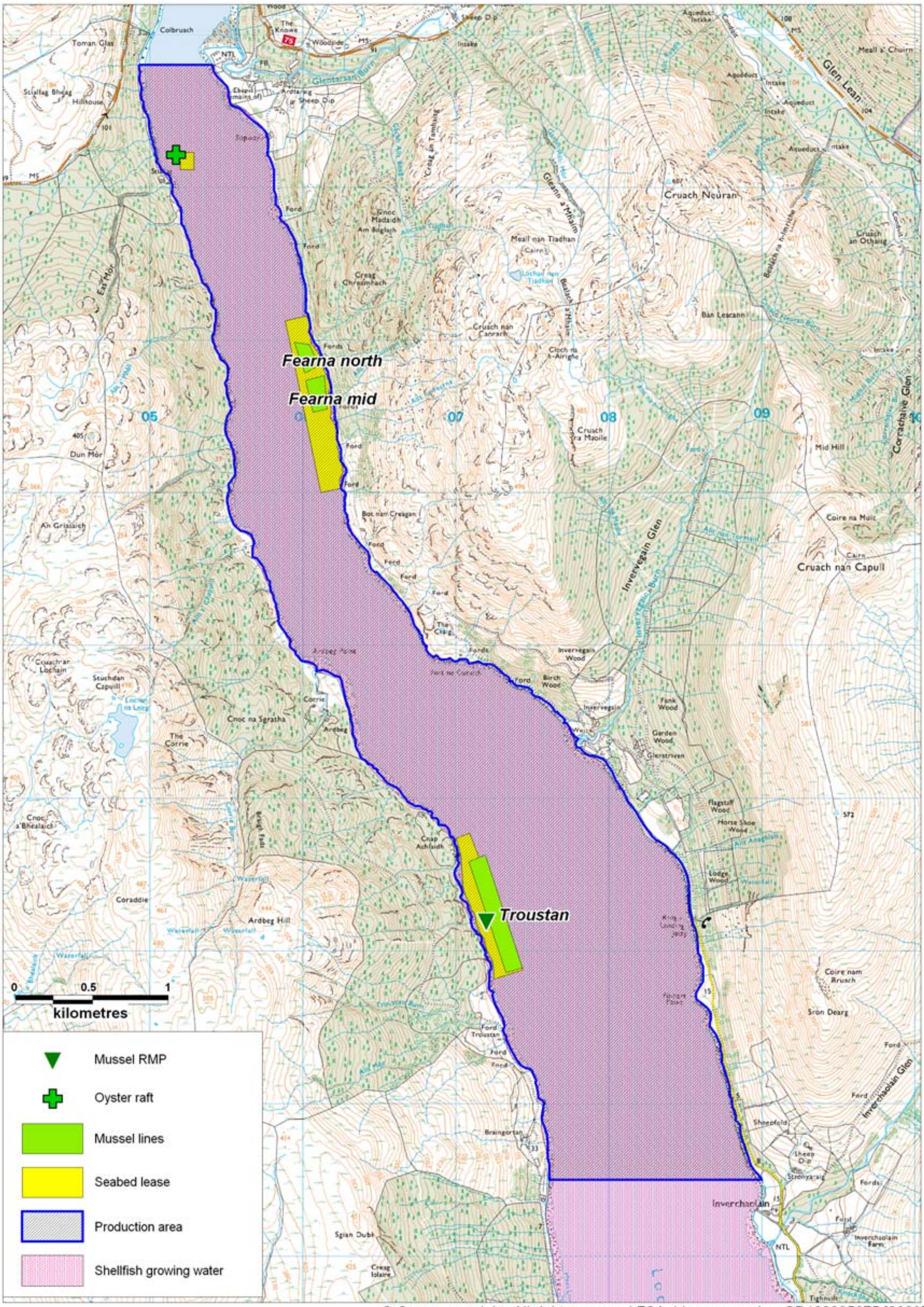


Figure 2.1 Loch Striven fishery

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the vicinity of Loch Striven at the 2001 census.

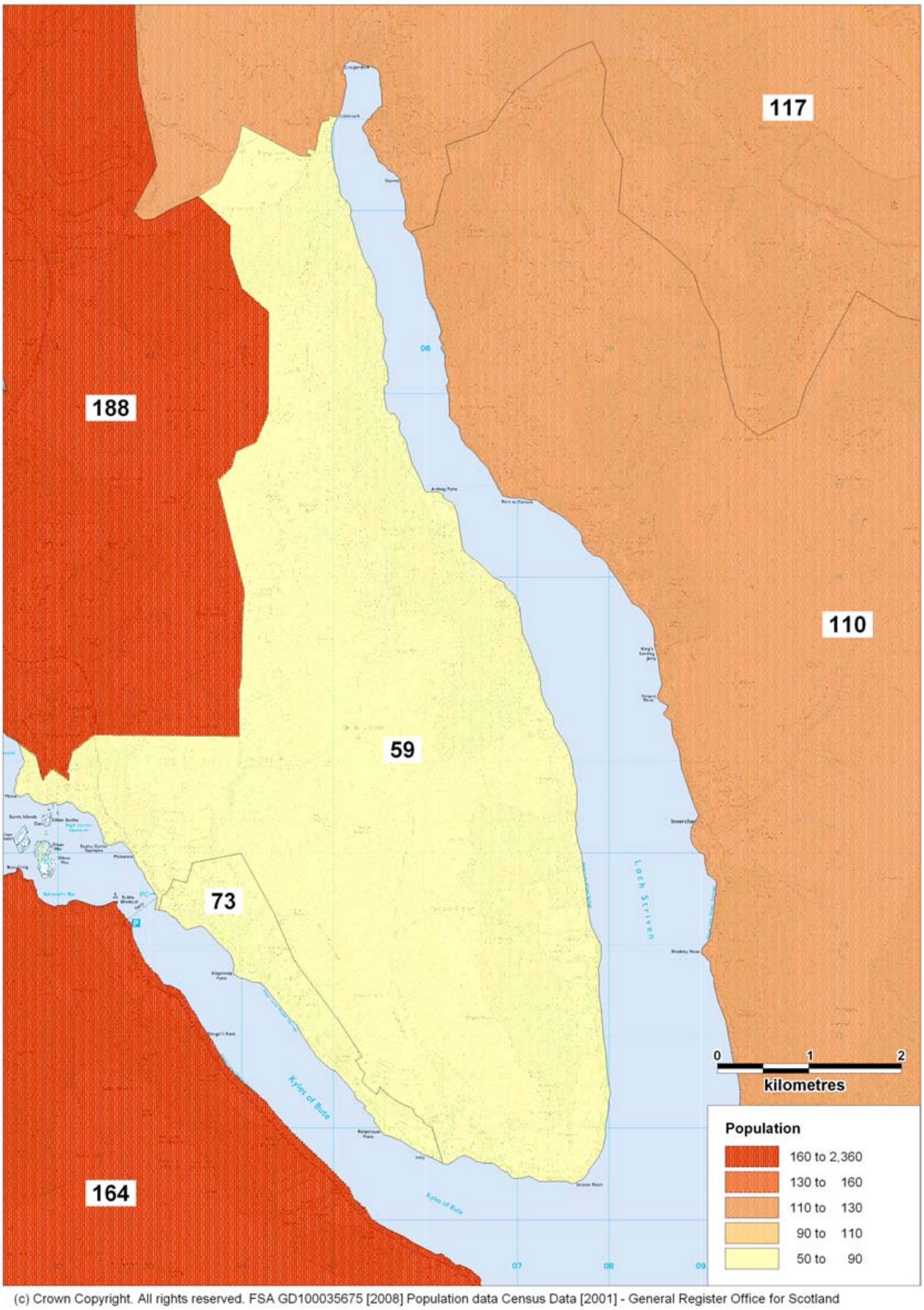


Figure 3.1 Population of Loch Striven

There are three population census output areas immediately bordering on Loch Striven, these are:

60QD000018	59
60QD000626	117
60QD000606	110
Total	286

The B836 loops around the head of the loch, where there are a few sparse settlements. There are no roads and only a small track along the southwestern shore of the loch and very little in the way of habitation. On the eastern shore, there is a small road along the southern end that ends less than 2km north of the southern production area boundary.

Dwellings are scattered throughout the surrounding census output areas at a very low density and there are no significant settlements directly adjacent to Loch Striven. There are no tourist facilities in the area. A local estate hosts a pheasant shoot in late autumn and winter, which would bring relatively small numbers of tourists to the eastern side of the loch during that time.

Therefore, it is not possible to highlight any one area that would be likely to increase the chances of faecal pollution from human sources to the fisheries.

4. Sewage Discharges

There were no community septic tanks and/or sewage discharges identified by Scottish Water for the area surrounding Loch Striven. SEPA identified one discharge consent within the catchment area of Loch Striven. Details are presented in Table 4.1.

Table 4.1 Discharge consents issued by SEPA

Ref No.	NGR of discharge	Discharge Type	Discharges to	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Comments
CAR/R/ 1017726	NS 0560 8397	Continuous	Loch Striven	Septic tank	NA	5	Septic tank discharge from Loch Striven Power Station. Not observed during shoreline survey.

There were no community septic tanks observed during the shoreline survey. A number of private sewer outfalls were recorded during the shoreline survey, and are listed in Table 4.2. None of these had SEPA consents.

Table 4.2 Outfall pipes observed during shoreline survey

No	NGR	Description
1	NS 07075 77467	Service barge that is moved around the farm. Was recorded in this location at the time of the shoreline survey. Has a toilet that is flushed using a bucket of seawater and discharges directly below the raft.
2	NS 07016 78846	White outfall pipe leading underground towards shore, discharge end not visible
3	NS 08095 78021	Outfall pipe from small house
4	NS 08529 77206	Outfall pipe, grey discharge cloud apparent

The locations of all discharges are mapped in Figure 4.1. Four fixed private discharges to Loch Striven were observed during the shoreline survey. Three are on east shore towards the southern end of the production area two to four kilometers south of the Fearna sites, and opposite the Troustan site. There is also a discharge to the head of the loch from the power station, which is about 3 km north of the Fearna sites. Therefore, an estimate of the total population equivalents discharging to Loch Striven from fixed discharges is about 20, none in very close proximity to the fisheries, so overall impacts from these discharges is expected to be minor. The discharge at the head of the loch is from a septic tank, but the others may be either raw or septic tank outfalls.

As there has historically been no requirement to register septic tanks within Scotland, it is possible that there are other unregistered discharges within the Loch Striven catchment area. It is presumed that all discharges direct to the production area were noted during the shoreline survey.

In addition to the fixed discharges, the barge servicing the mussel farm has an on board toilet which discharges directly below it when used. This barge is used to carry out work to both mussel sites, including harvesting. Typically, 3 or 4 people may be on board when the barge is in operation. If the toilet is used when the barge is near to the mussel lines, it could introduce both faecal indicator bacteria and pathogens directly to the fishery leading to localized impacts. An outbreak of oyster-borne gastrointestinal illness in the USA was traced back to the discharge of faecal waste overboard from harvesting boats (Kohn et al. 1995). This practise poses the single most significant risk to the microbiological quality of mussels grown on these sites.

Footnote:

Subsequent to the first drafting of this report, in late spring 2009, Maersk began laying up container ships at the southern end of the production area. By December 2009 the raft reached its maximum planned size of six ships.

The Argyll & Bute sampling officer confirmed that the ships were lying off Inverchaolain and a search of GeoGraph yielded a photograph and location. The ships appear to lie approximately 1.5 km south of the Troustan mussel lines, just inside the production area boundary and approximately in the centre of the loch. Further news from Argyll identified that the ships will be used as the set for a children's game show, with film crew and contestants to live aboard for the filming periof of six weeks beginning in April 2010.

Communication with the Maersk officer in charge of the raft confirmed that 12 crew were permanently stationed aboard the raft to maintain the ships and that all of the ships have Marpol-compliant onboard sewage treatment systems with a combined capacity of up to 165 persons. The treatment systems are desinged for black water only (wastewater from toilets). Grey water (wastewater from showers, laundry, sinks, etc.), which may have some bacteriological content, is discharged directly overboard.

Four of the ships have membrane bioreactor plants manufactured by Gertsen & Olufsen AS. Tests undertaken on one of the systems in 2005 showed final effluent to contain a mean of <1 faecal coliform / 100 ml MPN). If the system has been well maintained and continues to be operated efficiently, then it is not anticipated that this discharge would constitute a significant source of faecal contamination to the fishery. However, sewage treatment systems including membrane bioreactors, require a reasonably stable flow of sewage through the system to keep the biological filter alive and functioning efficiently. As inactive systems are brought on line due to higher demand, it is conceivable that there will be a time delay before the systems are functioning as well as they are designed to. In this case, bacteriological content of the effluent could be higher. Should untreated or partially treated effluent be discharged at any point, any impact to the fishery would be most likely to appear at the southern end of the Troustan site.

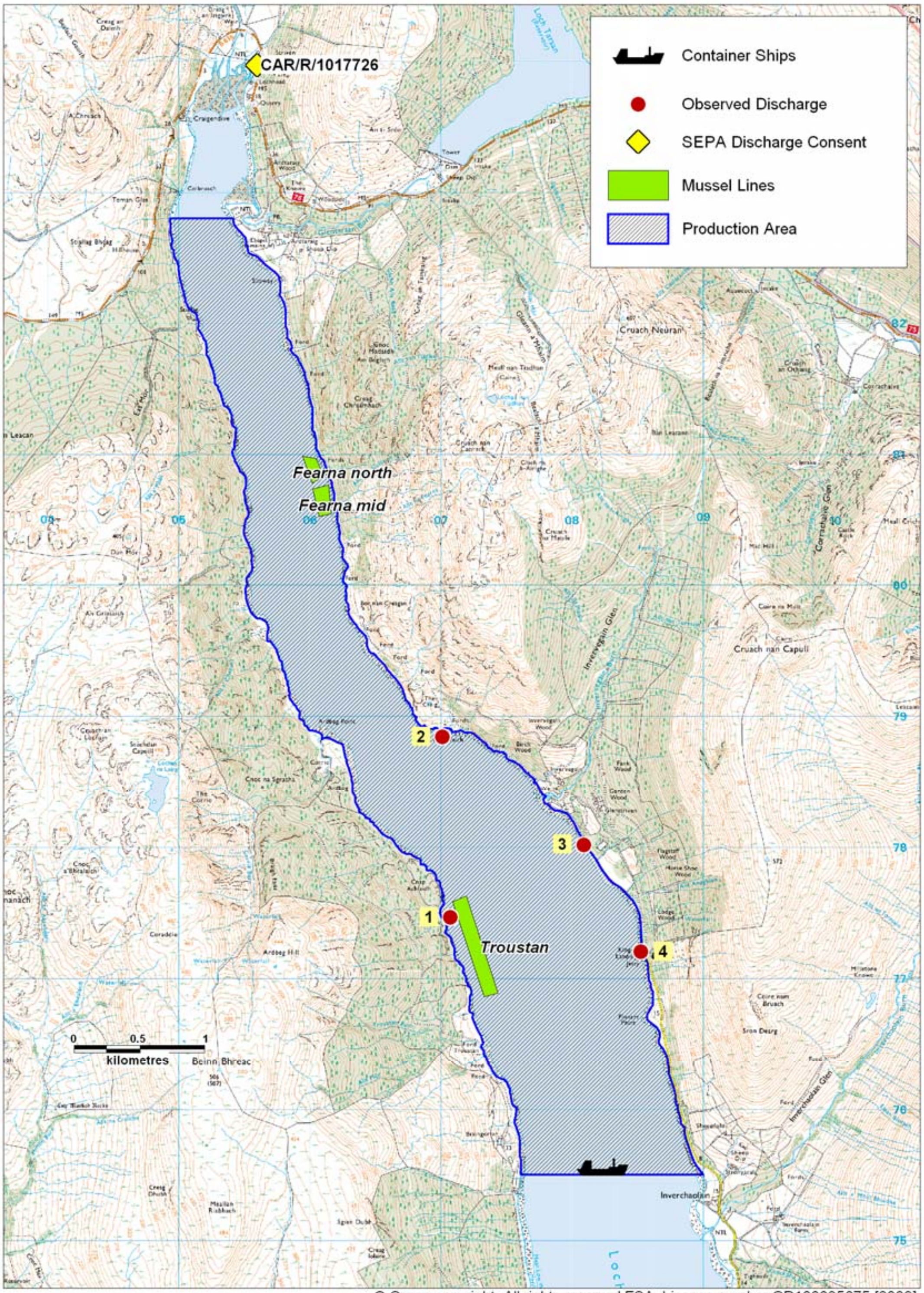


Figure 4.1 Sewage discharges at Loch Striven

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

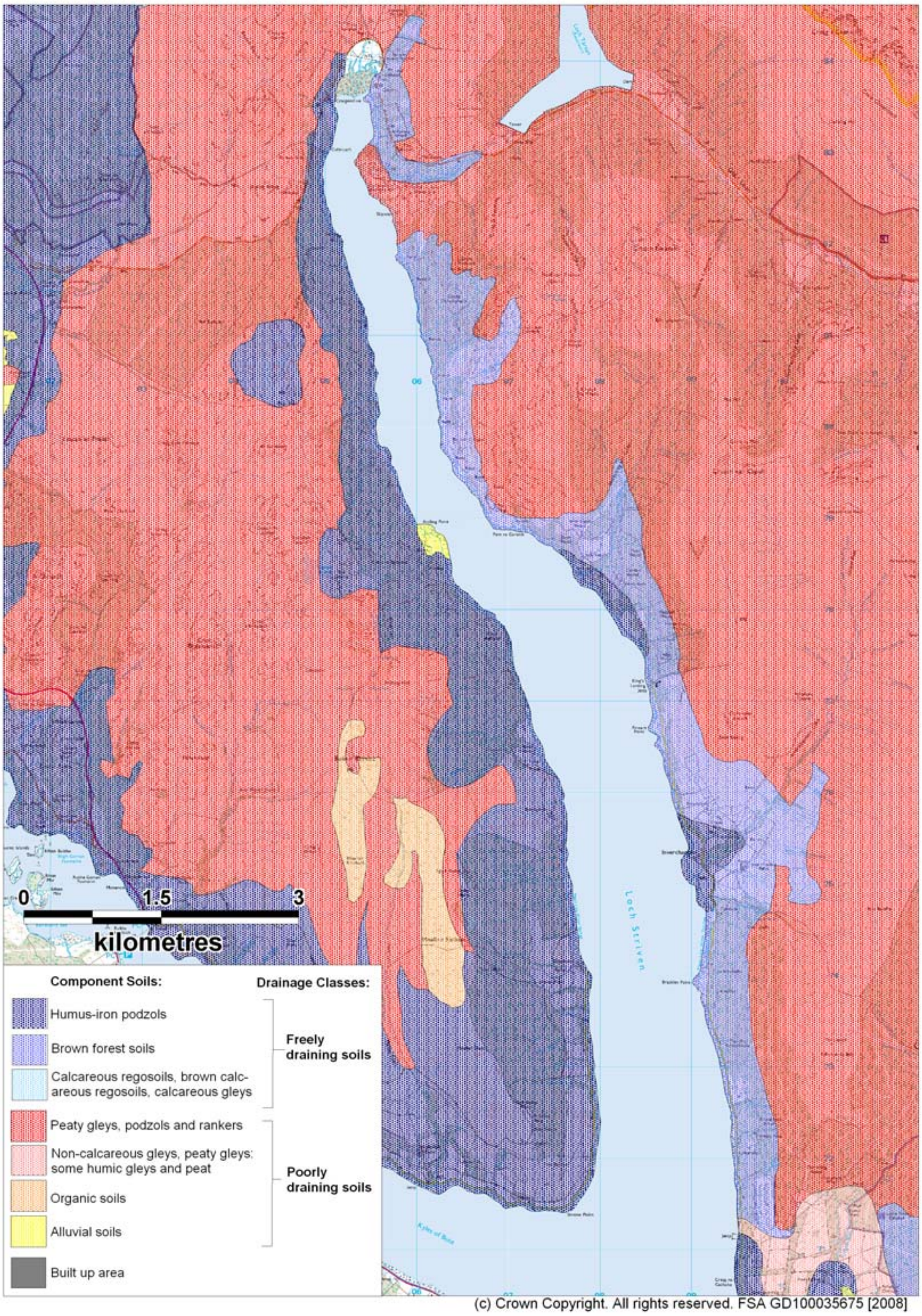


Figure 5.1 Component soils and drainage classes for Loch Striven.

Five types of component soils are recorded in the area of Loch Striven, three of which are poorly draining. Poorly drained soils predominate and are found over large inland areas on both sides of the loch.

Freely draining soils are found in a narrow strip along both shores of the loch, where the majority of discharges were observed. This strip is narrower on the eastern shore of the loch, particularly at the northern end. There are no built up areas recorded in the vicinity.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is therefore likely to be slightly higher along the eastern side of Loch Striven compared to the western side due to a larger area of poorly draining soils being present behind a smaller band of freely draining soils. Therefore, the impact would be greater at the Fearna site on the eastern side of the loch than at the Troustan site.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

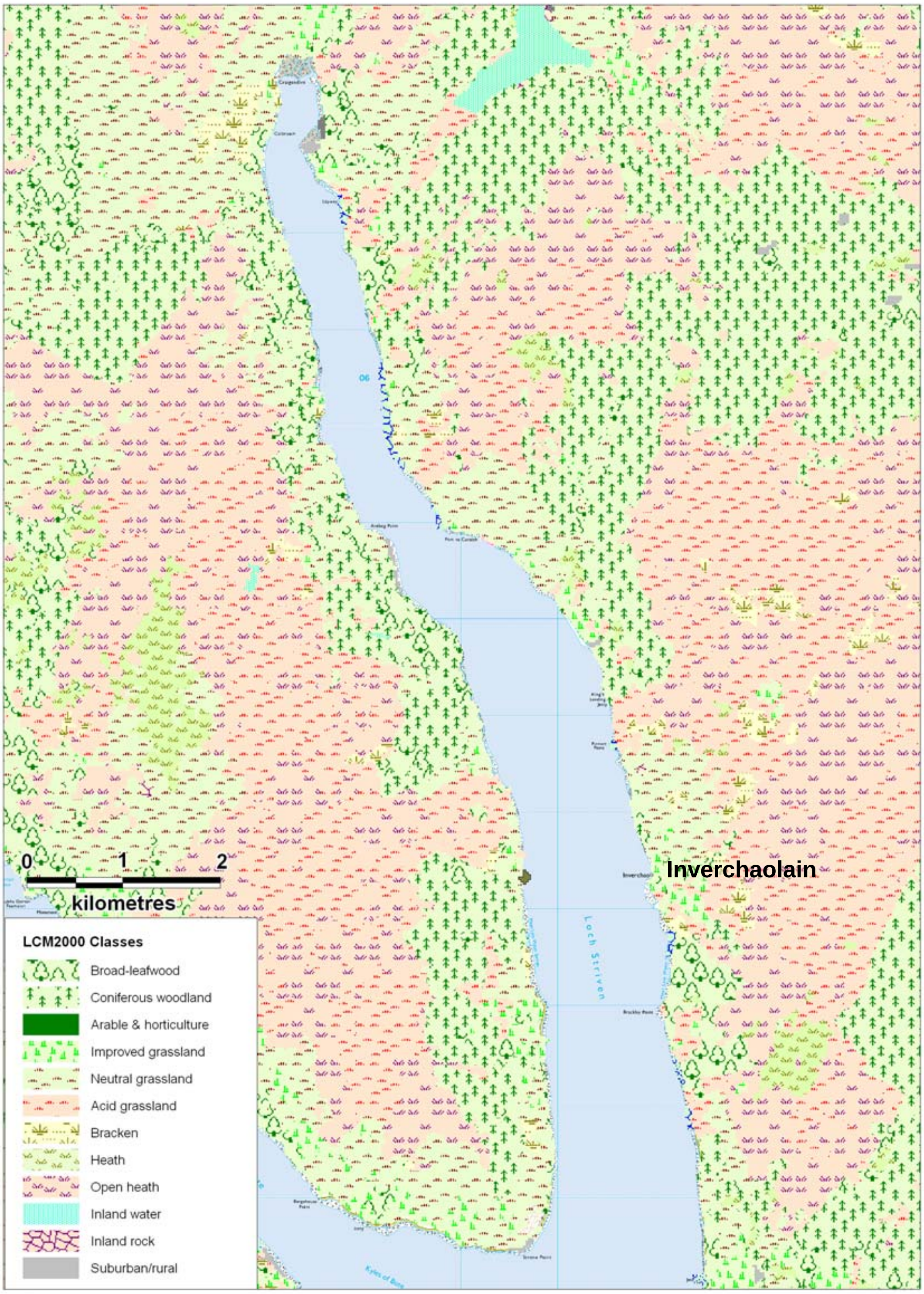


Figure 6.1 LCM2000 class land cover data for Loch Striven

Loch Striven is surrounded by a variety of land cover. The western shore is lined with a band of broadleaf and coniferous woodland, with an area of open heath and acid grassland further inland. The land cover along the eastern shore is a mixture of broad-leaf and coniferous woodland, some of which is plantation. Natural grassland (both acid and neutral) and open heath constitute the majority of the land cover. There are small patches of improved grassland dotted around both shores, with the largest areas at the head of the loch and around Inverchaolain, which lies south of the production area boundary on the east shore of the loch.

The LCM2000 data shows a small suburban/urban development at the very northern end of the loch. This corresponds loosely with the location of the Ardtaraig estate and the shore base for the mussel operation. While there is some hard standing here, it is limited and so not entirely consistent with the LCM2000 description.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^{9} cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^{8} cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^{8} cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

On this basis, the highest contribution may be expected from the areas of improved grassland dotted around the shores, and low contributions are expected from the other land cover types. A higher faecal coliform contribution might be expected from the small area of hardstanding at the Ardtaraig estate and also from the roads around the shoreline, however these areas are extremely limited in comparison to the other land cover types.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data was requested from the Scottish Government. Agricultural census data was provided by RERAD for the parish of Inverchaolain. The parish of Inverchaolain covers the whole area surrounding Loch Striven. Reported livestock populations for the parish in 2007 and 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data.

Table 7.1 Livestock census data for Inverchaolain parish

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	0	-
Total poultry	*	*	*	*
Total cattle	*	*	*	*
Total sheep	6	5448	6	5299
Deer	0	-	0	-
Horses and Ponies	*	*	*	*

* Data withheld on confidentiality basis.

Pigs were no longer farmed in this parish by 2008. Deer were not present in either 2007 or 2008. Poultry, cattle and horses and ponies are farmed somewhere within the parish boundaries, however specific data on numbers could not be provided. Due to the large area of the parish, this data does not provide information on the livestock numbers in the area immediately surrounding Loch Striven. The only information specific to the area near the shellfishery was therefore the shoreline survey (see Appendix), which relates specifically to the time of the site visit on 14-15 October 2008. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

This confirmed that sheep were the predominant species farmed in the area. At the head of the loch, 29 sheep were observed grazing on pasture adjacent to the burn, and a further 45 sheep were observed at the Ardtaraig Estate. Twelve sheep were observed at Troustan, and 20 cattle were observed just south of Troustan on the opposite shore. Just over 2km southeast of the Troustan site is Inverchaolain farm with some area of improved pasture and presumably livestock, though this location was not visited during the shoreline survey, so no specific information on livestock present there is available.

The overall density of livestock is low, and the forested areas around the loch unsuitable for grazing. As the remaining area is rough grassland rather than improved pasture, it is expected that sheep particularly will move about large ranges and that the animals observed during the survey are unlikely to be present in those locations for extended periods.

As there is little foreshore around the loch, any impacts from livestock are most likely to be carried via streams draining grazed areas rather than via direct deposition at the shoreline.
Although a small number of sheep were observed grazing near to the shoreline less than 500 m to the south of the Troustan site, larger numbers of livestock were observed on improved pasture between 1.5 and 3 km north of the Fearna sites. It is likely that while Troustan may be impacted by faecal waste from the small area grazed to the south, the grazing north of Fearna may receive greater levels of deposition due to the larger number of animals it supports.

Faecal bacteria originating from grazing livestock are most likely to be carried to the loch via streams and burns, and so the bulk of the impact is likely to occur via freshwater input to the loch rather than via direct deposition at the shoreline.

Generally, numbers of livestock in the area would be expected to increase in spring, when lambs and calves are born, and then decrease again in autumn when they are sold off or sent for slaughter, so higher impacts would be expected between late spring and autumn.

The Glenstriven Estate hosts a pheasant shoot and over 150 pheasants were observed on the east shore of the loch during the shoreline survey. The general practice at such estates is for captive reared young pheasants to be stocked out into pens around July. They remain in these pens for 3-6 weeks, until they are large enough to fly out. They are provided food from feeding stations, around which they may tend to congregate. They tend to prefer wooded areas, although they will also frequent more open areas, so the numbers recorded during the shoreline survey are likely to represent only a small fraction of the birds present at the time. Pheasant shooting season runs from October to February. Although there will be pheasants present in the area year-round, the overall population will be considerably lower in the first half of the year (W. Beaumont, Game and Wildlife Conservation Trust, pers comm.). Any impacts from pheasants are likely to occur mainly on the east shore, and will be higher in the second half of the year. Contamination from these birds will mainly be carried to the production area via streams draining wooded areas.

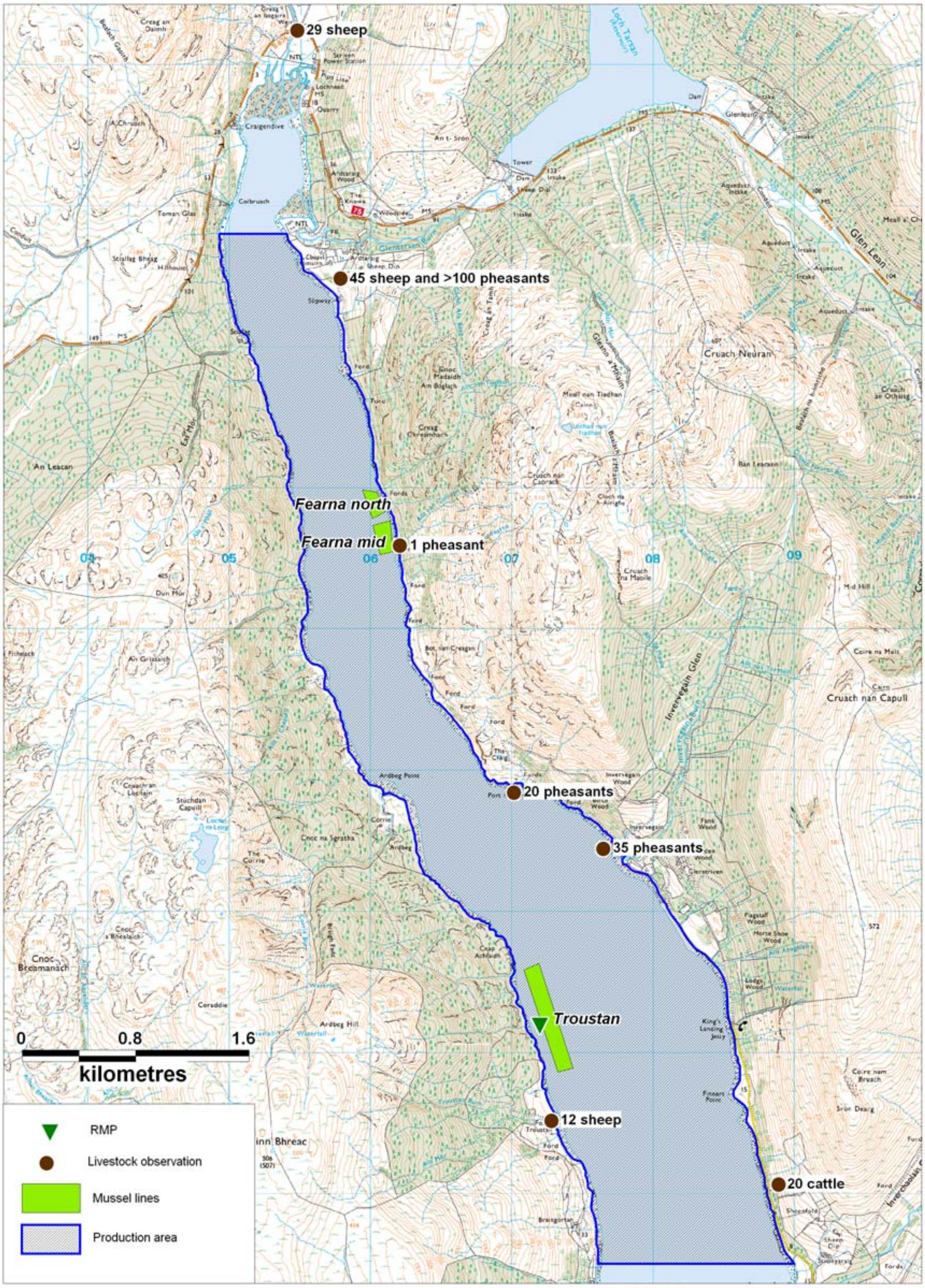


Figure 7.1 Livestock observations at Loch Striven

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present at Loch Striven could potentially affect water quality around the fishery.

Seals

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 1996 estimated a population of 991 common seals within the area named 'Clyde Estuary' (Southend to Loch Ryan). This is large stretch of coastline which includes the east coast of the Kintyre, Loch Fyne, the Clyde estuary and the whole of the Ayrshire coast, so overall densities are low. The exact locations of the haul out sites were not specified. One seal was seen at the Troustan site during the course of the shoreline survey.

Seals will range widely hunting for food and it is apparent that seals may be present near the fishery. The population is likely to be relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited in time and area and unpredictable.

Whales/Dolphins

Whales and dolphins are relatively common off the west coast of Scotland and sightings are recorded by the Hebridean Whale and Dolphin trust. These are reported to the trust by ferry skippers, whale watch boats and other observers and are listed in Appendix 4.

It is possible that some of the smaller cetaceans may be present from time to time, but the larger species are unlikely to be seen in this shallow enclosed water body. Any presence, however, is likely to be fleeting and unpredictable and so will not be taken into account with regard to establishing sampling plans for Loch Striven.

Birds

A number of bird species are found in the vicinity of Loch Striven. Of these, seabirds and waterfowl are the most likely to be found on or near the fisheries in significant numbers.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census. The area was surveyed in late spring of 1999. Total counts of all species recorded within 5 km of the production area are presented in Table 8.1. Counts were of occupied territories or nests, so each count represents a breeding pair.

Table 8.1 Seabird counts within 5km of the area

Common name	Species	Count	Method
Common Gull	*Larus canus*	86	Occupied territory
Herring Gull	*Larus argentatus*	1	Occupied territory/nests
Great Black-backed Gull	*Larus marinus*	1	Occupied territory

Overall, relatively few breeding seabirds were recorded in the vicinity of the fishery. The majority of these birds were seen at the Loch Tarsan Reservoir, about 2 km NE of the production area. Although nesting occurs in early summer and the birds may be more concentrated around nesting sites at this time, gulls are likely to be present in the area throughout the year. Therefore, it is likely that significant numbers of gulls will be present within the production area all year. About 100 gulls and cormorants were seen on the mussel floats during the shoreline survey. In the absence of more specific data on the distribution of roosting and nesting sites near to the fishery, the spatial distribution of any impact will be assumed to be random and thus will not be accounted for in the final assessment and sampling plan.

The harvester reports that eider ducks frequent the area between November and May sometimes in large numbers (thousands) but none was seen during the shoreline survey. The Troustan site had predator netting in place at the time of survey, which the grower advised was effective at keeping the ducks from this site so he had plans to install similar at the Fearna site. Until such time, higher impacts from ducks may be expected at the Fearna site during the winter and spring. Herons, oystercatchers and swans were observed during the shoreline survey, but none in large concentrations.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Deer will be present particularly in wooded areas where the habitat is best suited for them. The majority of the shoreline of Loch Striven is wooded. While no population data were available for this specific area, it can be presumed that it hosts a significant population of deer, and deer faeces were recorded during the shoreline survey. It is likely that a proportion of the indicator organisms detected in the streams feeding into Loch Striven will be of deer origin, though in the absence of more detailed information about population and distribution it will be assumed that their distribution is random and any impact even spread across the fishery.

Otters

No otters were observed during the course of the shoreline survey, although otters are likely to be present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be minor.

Summary

Potential wildlife impacts to the fisheries at Loch Striven include those from gulls, ducks and other waterbirds, deer, seals and otters. Gulls may be a significant source of contamination as they were observed resting on the mussel floats. A seal was also observed resting on the mussel lines so seals may cause significant localised impacts. Impacts from eider ducks may be expected mainly at the Fearna site during the winter and spring. Impacts from other wildlife species are likely to be of lesser significance. Whilst it is likely that some contamination in the area is of wildlife origin, there is no specific information available to suggest that any particular area is more heavily impacted by wildlife than any other.

9. Meteorological data

The nearest weather station is located at Benmore, approximately 9 km to the north east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). It is likely that the rainfall experienced at Benmore is similar to that experienced at the production area due to their close proximity.

The nearest major weather station where wind is measured is located at Glasgow: Bishopton, approximately 45 km to the east of the production area. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/1996 to 31/12/2007. It is likely that there are broad similarities in wind patterns between the production area and the weather station, such as seasonal variations in wind strength. However, given the differences in local topography distance between the two and it is likely that the patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

Total annual rainfall and mean monthly rainfall were calculated, and are presented in Figures 9.1 and 9.2.

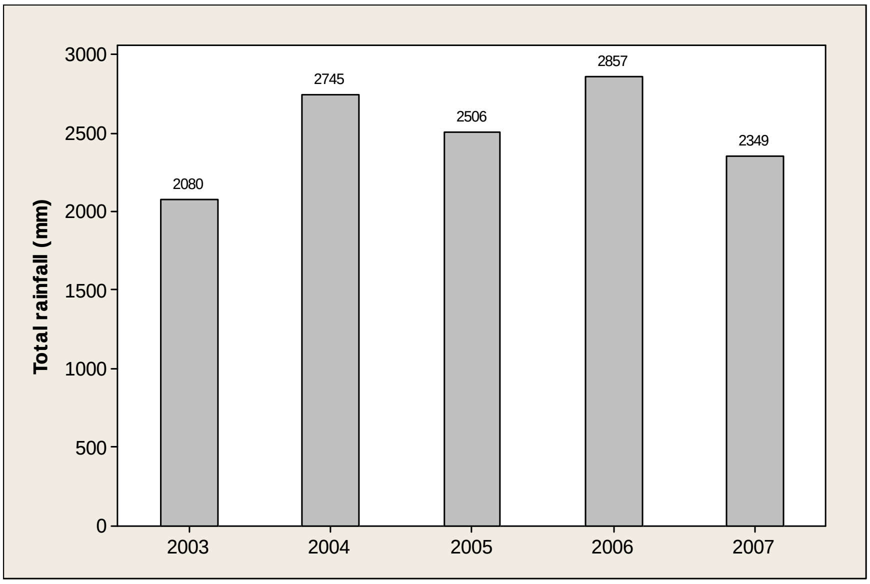


Figure 9.1 Total annual rainfall at Benmore, 2003 – 2007

Rainfall varied significantly from year to year during the period, with the 2006 total representing a 37% increase over the 2003 total. Substantial seasonal variation in average rainfall is apparent in Figure 9.2.

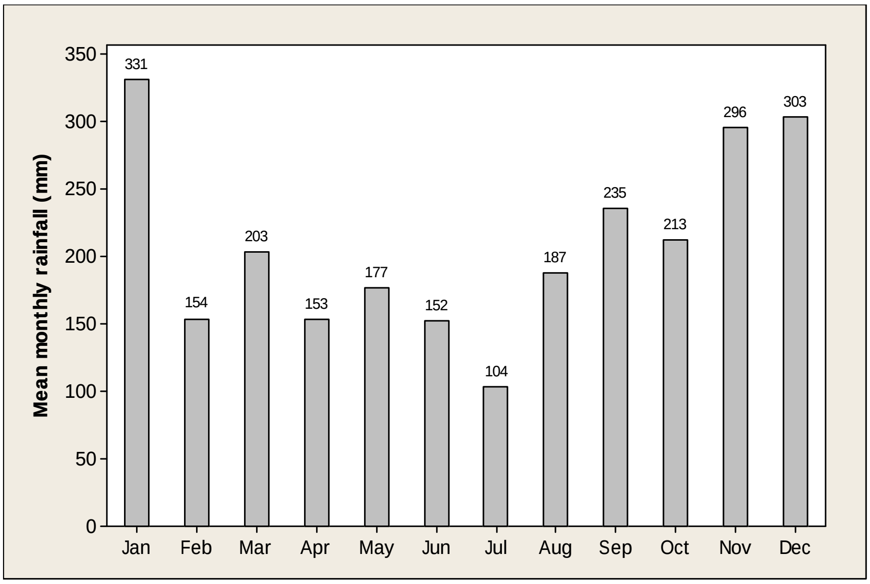


Figure 9.2 Mean total monthly rainfall at Benmore, 2003 - 2007

The wettest months were November, December and January, while the driest month was July. For the period considered here, 42% of days experienced rainfall of 1 mm or less, and 25% of days experienced rainfall of 10 mm or more.

Periods of increased rainfall are generally associated with higher levels of contaminated surface water runoff. Marked changes in the level of rainfall may also caus significant runoff of accumulated faecal material. Faceal contaminants from some sources may be independent of rainfall and so episodes of contamination may occur outside identified periods of higher rainfall, for example when livestock are present on the shoreline.

9.2 Wind

Wind data collected at the Glasgow: Bishopton weather station is summarised by season and presented in figures 9.3 to 9.7.

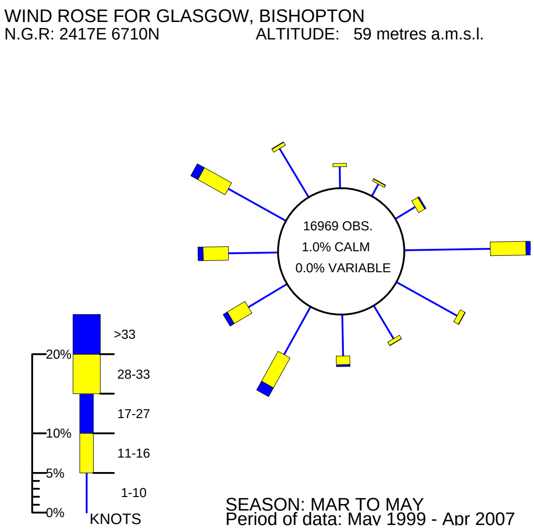


Figure 9.3 Wind rose for Glasgow: Bishopton (March to May)

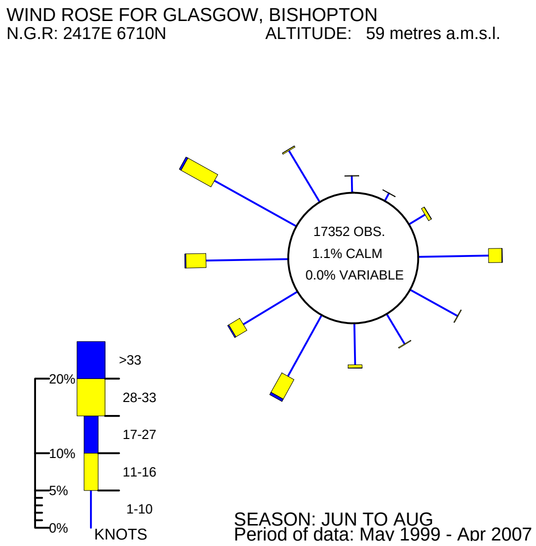


Figure 9.4 Wind rose for Glasgow: Bishopton (June to August)

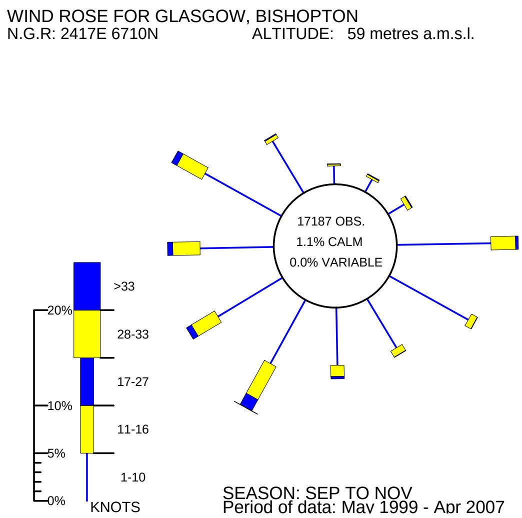


Figure 9.5 Wind rose for Glasgow: Bishopton (September to November)

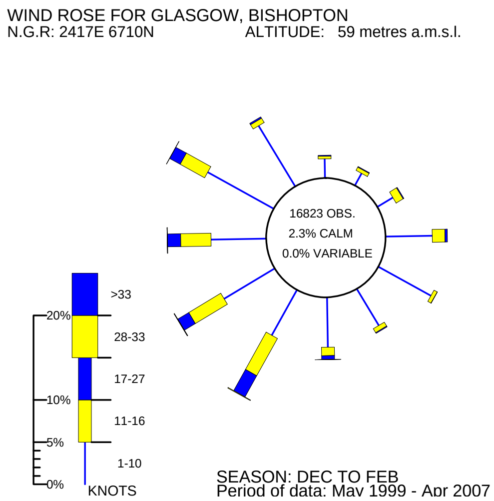


Figure 9.6 Wind rose for Glasgow: Bishopton (December to February)

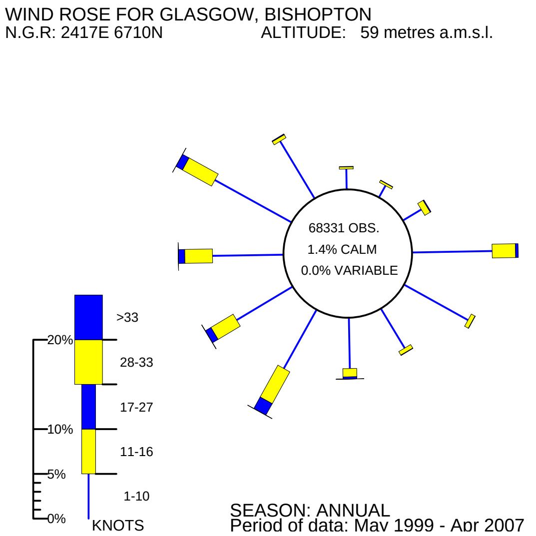


Figure 9.7 Wind rose for Glasgow: Bishopton (All year)

Glasgow is not one of the windier areas of Scotland, with a low frequency of gales compared to places such as the Western Isles and the Shetlands. The wind roses show that the overall prevailing direction of the wind is from the west, and the strongest winds come from this direction. Stronger winds are also experienced from the east, presumably due in part to local topography - Bishopton is in the Clyde Valley, which has a west to east aspect. Winds are generally lighter during the summer months and stronger in the winter.

Loch Striven has a south to north aspect, opening out into the Firth of Clyde at its mouth. The Isle of Bute lies near its mouth giving some shelter from the open sea. Loch Striven is about 15 km long and up to 1.5 km wide, and lies in a steep sided valley surrounded by hills rising to over 600 m in places. The loch will receive shelter from winds from most directions, but is more open to southerly or northerly winds, which would be funnelled up or down the Loch by the surrounding land. Therefore, the pattern of wind directions at the fishery are likely to align more along the north south axis than those at Glasgow.

A strong southerly wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, above the normal high water mark, into the loch.

Although tidally driven circulation of water in the Loch is likely to be important due to its relatively large tidal range, wind effects are likely to cause significant changes in water circulation. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s in the direction of the wind. These surface water currents create return currents which may travel along the bottom or sides of the loch depending on bathymetry. Either way, strong winter winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. There may be some instances where contamination from point sources may be carried to production sites by wind driven currents.

10. Current and historical classification status

Loch Striven has been classified for the production of mussels since before 2001. The classification history for mussels from 2001 is presented in Table 10.1. The area was classified as a seasonal A/B for mussels in all years apart from 2002 when it was classified as an A. The RMP for the production area is currently located at NS 072 772, which lies about 10 m to the west of the Troustan site, well within the 100 m level of accuracy expected when estimating a grid reference from and Ordnance Survey map. A map of the production area is presented in Figure 10.1

Table 10.1 Classification history, Loch Striven, mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	B	B	B	B	B	B
2002	A	A	A	A	A	A	A	A	A	A	A	A
2003	A	A	A	A	A	A	A	A	A	A	A	B
2004	A	A	A	A	A	A	A	A	A	A	A	B
2005	A	A	A	A	A	B	B	B	B	B	B	B
2006	B	B	A	A	A	B	B	B	B	B	B	B
2007	B	B	A	A	A	A	B	B	B	B	B	B
2008	B	A	A	A	A	B	B	B	B	B	B	B
2009	B	A	A									

Loch Striven was also classified for the harvest of Pacific oysters from 2003 to 2005. It was declassified in 2006 as insufficient samples were submitted during 2005. The classification history is presented in Table 10.2. The site was classified as B in 2003 and a seasonal A/B in 2005. There is currently no RMP for the oyster fishery as it is not in commercial production.

Table 10.2. Classification history, Loch Striven, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	B	B	B	B	B	B	B	B	B	B	B	B
2004	A	A	A	A	B	B	B	B	B	B	A	A
2005	A	A	A	A	B	B	B	B	B	B	A	A

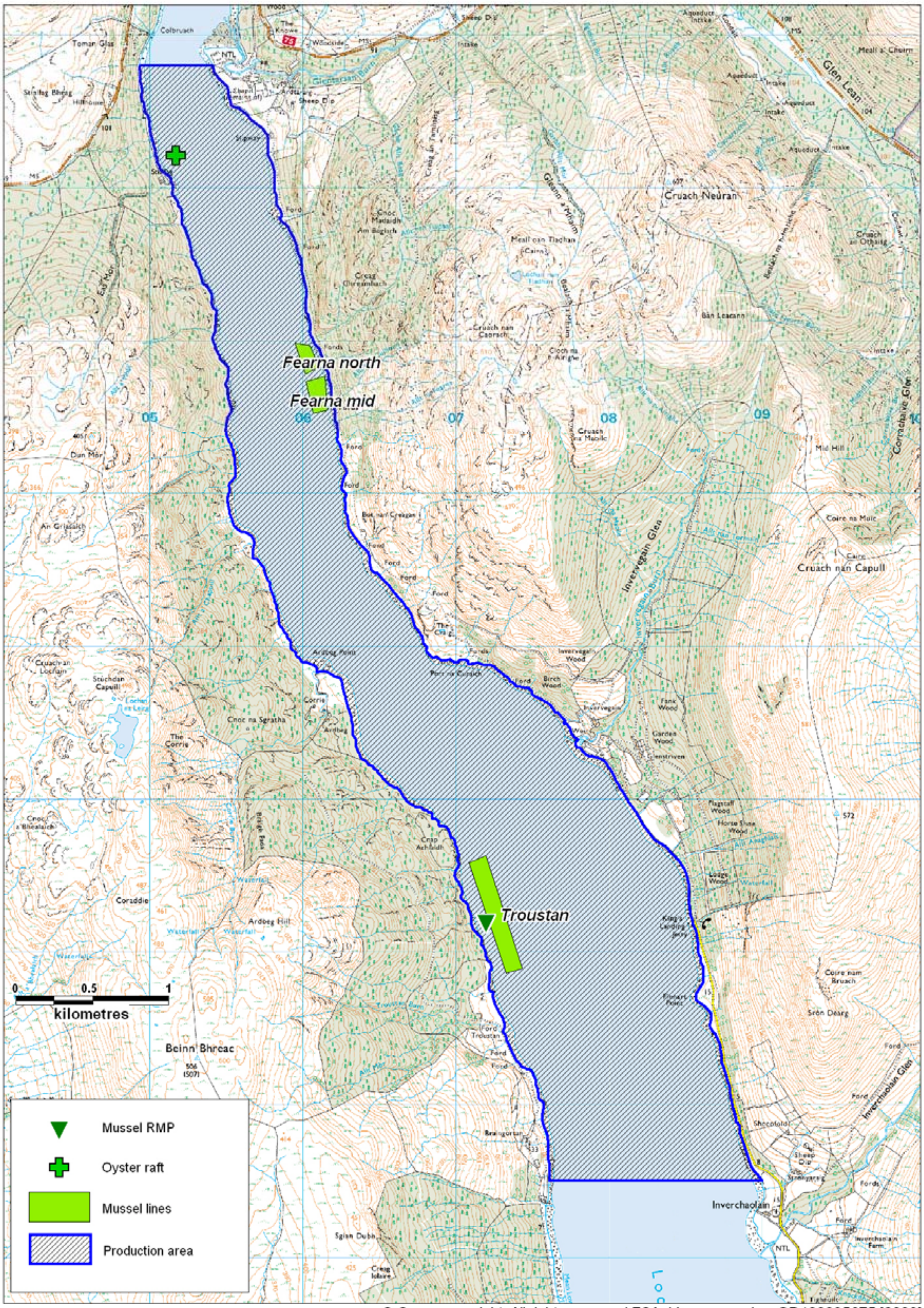


Figure 10.1 Current production area

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Loch Striven from the beginning of 2002 up to the end of 2007 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Three common mussel samples were discarded from the analysis as they had no recorded sampling location. One horse mussel sample was discarded from the analysis as its reported sampling location was 15 km north of the production area, and another horse mussel sample was discarded as its reported sampling location was 2.3 km west of the production area. All samples were analysed within two days of collection.

Three Pacific oyster and 8 common mussel samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results by location is presented in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary						
Production area	Loch Striven	Loch Striven	Loch Striven	Loch Striven	Loch Striven	Loch Striven
Site	Troustan	Troustan	Troustan	Loch Striven	Troustan	Loch Striven
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Pacific oysters
SIN	AB-205-63-8	AB-205-63-8	AB-205-63-8	AB-205-62-8	AB-205-63-8	AB-205-62-13
Location	NS072772 (RMP)	NS073770	NS073769	NS053822	NS071775	NS053822
Total no of samples	59	4	3	3	1	21
No. 2002	9	0	0	0	0	6
No. 2003	8	0	0	3	0	8
No. 2004	17	0	0	0	0	7
No. 2005	12	0	0	0	0	0
No. 2006	12	0	0	0	0	0
No. 2007	1	4	3	0	1	0
Results Summary						
Minimum	<20	20	50	40	40	<20
Maximum	3500	16000	2400	110	40	9100
Median	70	385	70	90	40	160
Geometric mean	97.0	263	203	73.4	40	218
90 percentile	550					5400
95 percentile	1120					9100
No. exceeding 230/100g	17 (29%)					8 (38%)
No. exceeding 1000/100g	4 (7%)					6 (29%)
No. exceeding 4600/100g	0 (0%)					3 (14%)
No. exceeding 18000/100g	0 (0%)					0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling locations (with OS grid reference, species, number of samples and sampling dates). The majority (80%) of mussel samples were collected from NS072772, which is the RMP. Only three mussel samples were taken at the Loch Striven site, and no mussel samples were taken from the Fearna sites. As the maximum number of samples taken from the other sampling locations was four, no statistical tests were carried out to evaluate whether there were significant differences in results between the sampling locations. All oyster samples were reported as having been taken from one location (NS053822).

A comparison of results from the Troustan and Loch Striven sites shows higher mean and peak results at the Troustan site. However, only three samples were taken from the Loch Striven site, and these were all taken on the same day, and the Troustan site was not sampled on this occasion. Therefore, this does not constitute a robust comparison of levels of contamination at these two sites.

Figure 11.1 gives the impression of higher levels of contamination towards the southern end of the Troustan site, although this may be misleading given the low sample numbers reported from locations other than the RMP. No two locations were sampled on the same occasion so the results are not directly comparable. The highest individual result of 16000 *E. coli* MPN/100g was reported from NS 073 770 on 12/07/2008. This sample was taken towards the south end of the site, about 230 m to the south of the RMP. As no samples were taken from the Fearna site, it is not possible to ascertain whether variation in contamination levels observed in the monitoring program are due to spatial or temporal factors at this site.

Footnote:

For 23 samples taken between 2008-2009 all but one were reported from locations within the northern half of the mussel farm at Troustan. Comparing the geometric mean of these results with those obtained from 2007 at the southern end of the site showed that there was very little difference between the two, with results only slightly higher at the southern end. The peak result of >18000 came from the northern end of the site. As there is little spatial difference in potential sources here, it is possible that incidences of contamination may be coming from the barge toilet.

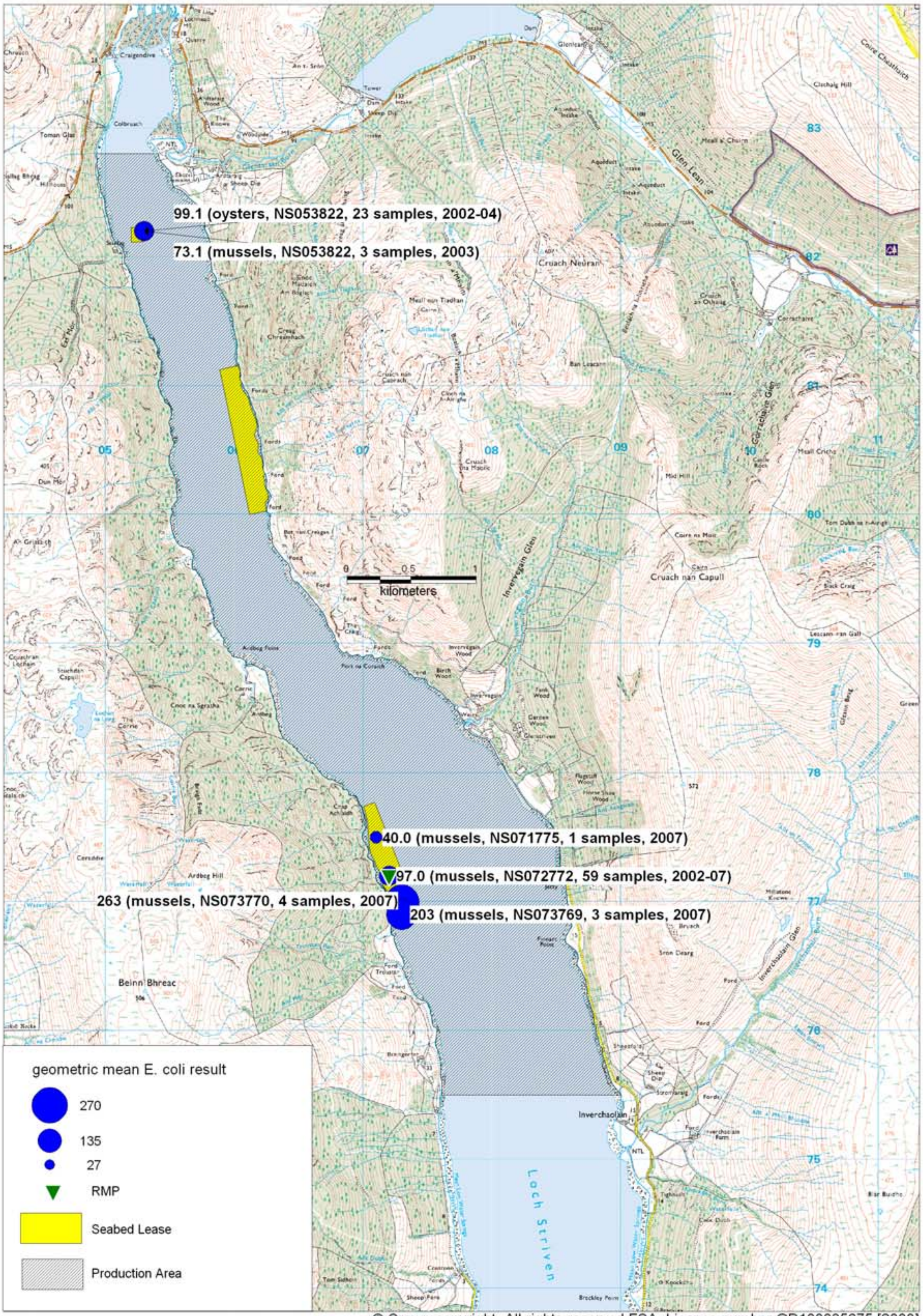


Figure 11.1 Map of sampling points and geometric mean result

11.4 Overall temporal pattern of results

Figures 11.2 and 11.3 present scatter plots of individual results against date for all mussel and oyster samples taken from Loch Striven. Trend lines calculated using a Loess regression function are presented on both plots.

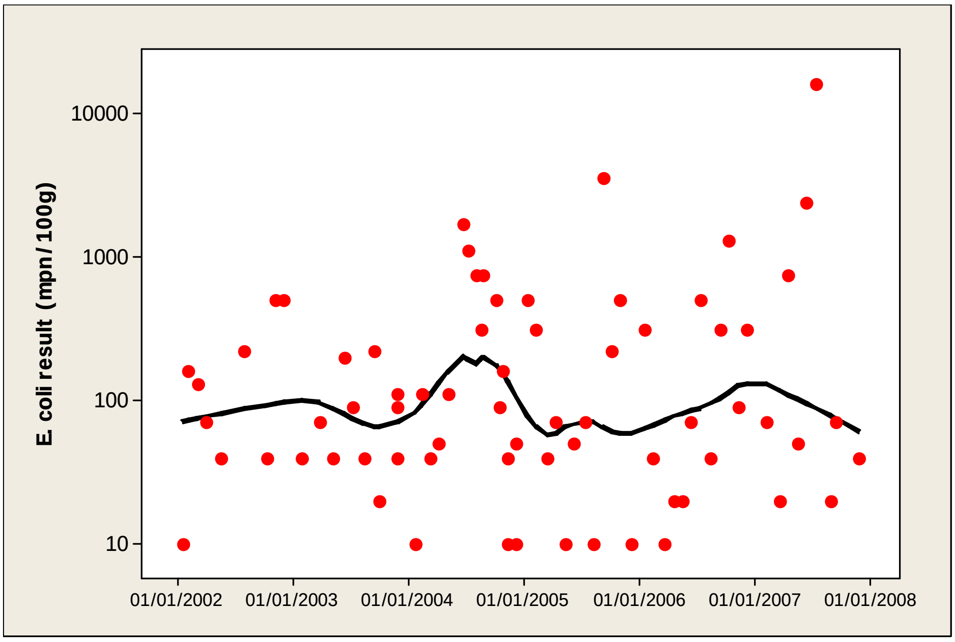


Figure 11.2 Scatterplot of mussel results by date with loess smoother

No obvious overall improvement or deterioration, or trends or cycles can be seen in Figure 11.2, but it suggests peaks in results in mid 2004 and early 2007.

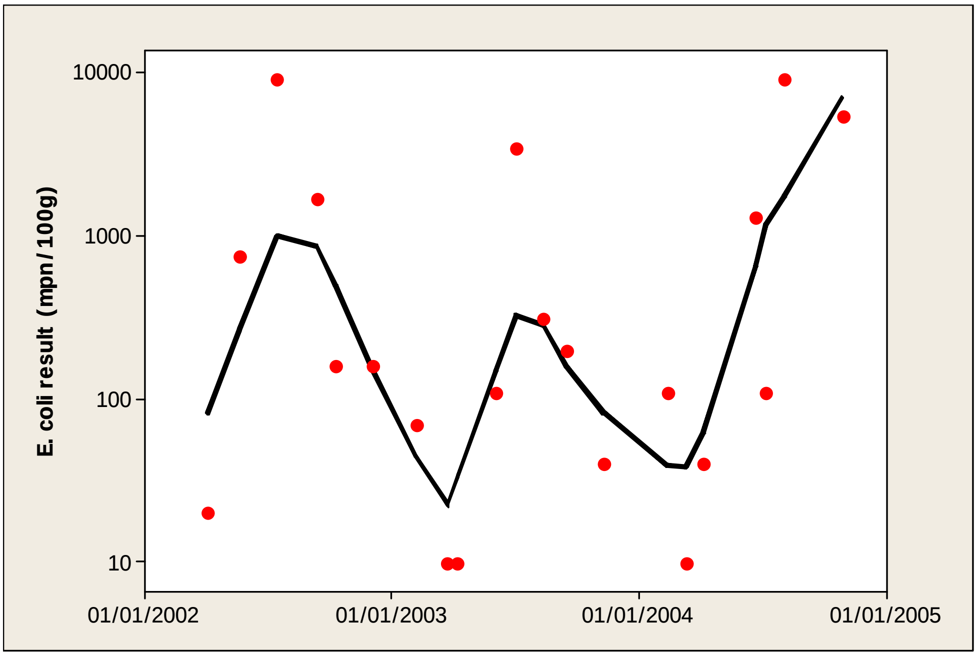


Figure 11.3 Scatterplot of oyster results by date with loess smoother

Figure 11.3 suggests peaks in oyster results have occurred during the summer.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and may cause seasonal patterns in results. Figures 11.4 and 11.5 present the geometric mean *E. coli* result by month (+ 2 times the standard error) for mussels and oysters respectively. Higher results occurred during the warmer months.

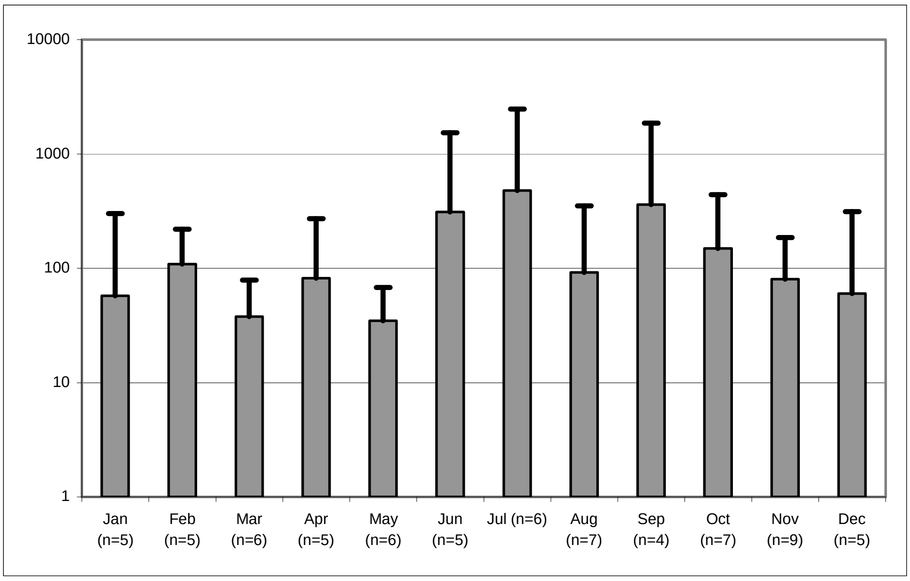


Figure 11.4 Geometric mean result by month (mussels)

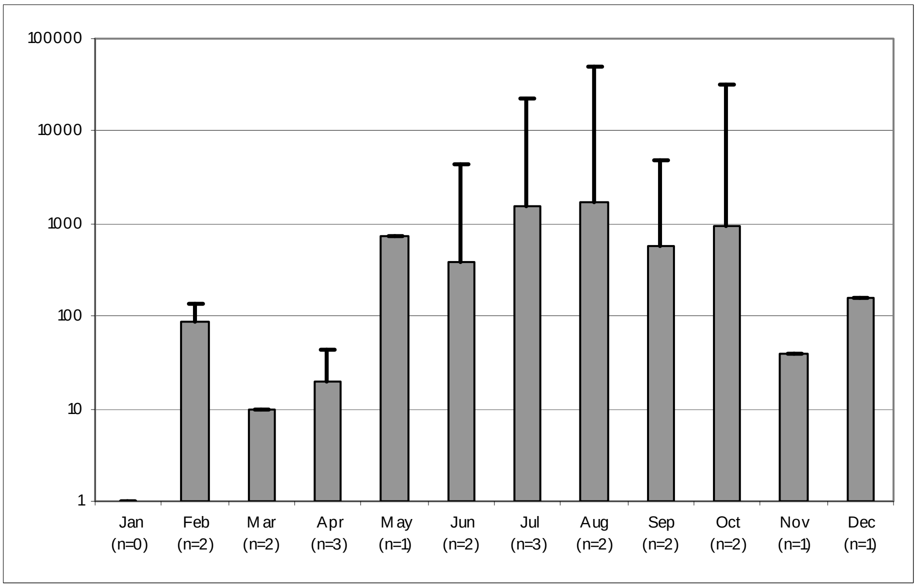


Figure 11.5 Geometric mean result by month (Oysters)

Sample numbers were low for oysters, but this confirms the observation in Figure 11.3 that higher results occurred during the warmer months.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

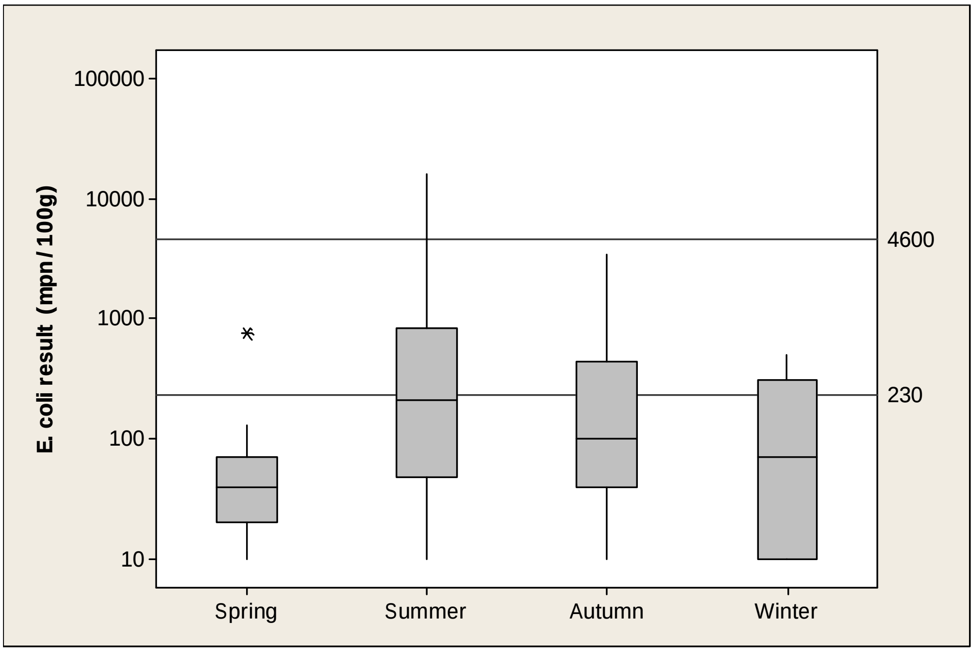


Figure 11.6 Boxplot of result by season (mussels)

A significant difference was found between results by season for mussels (One-way ANOVA, p=0.016, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer were significantly higher than those in the spring.

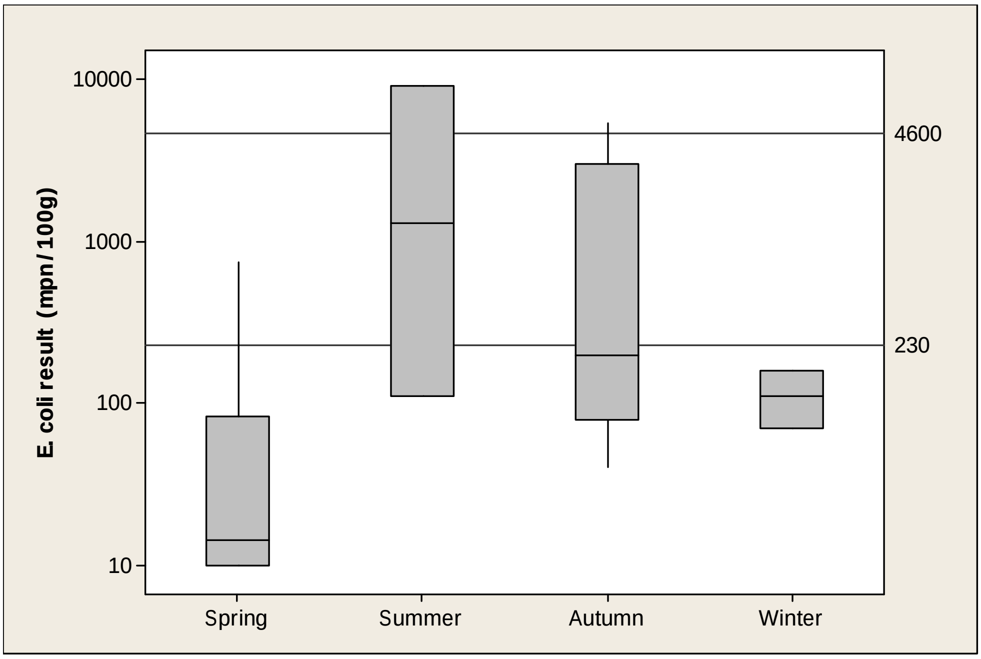


Figure 11.7 Boxplot of result by season (oysters)

A significant difference was found between results by season for oysters (One-way ANOVA, p=0.013, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer were significantly higher than those in the spring.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is Benmore, approximately 9 km to the north east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). Figure 11.8 presents a scatterplot of *E. coli* results against rainfall for mussels, Figure 11.9 presents the same for oysters. Spearman's Rank correlations were carried out between results and rainfall.

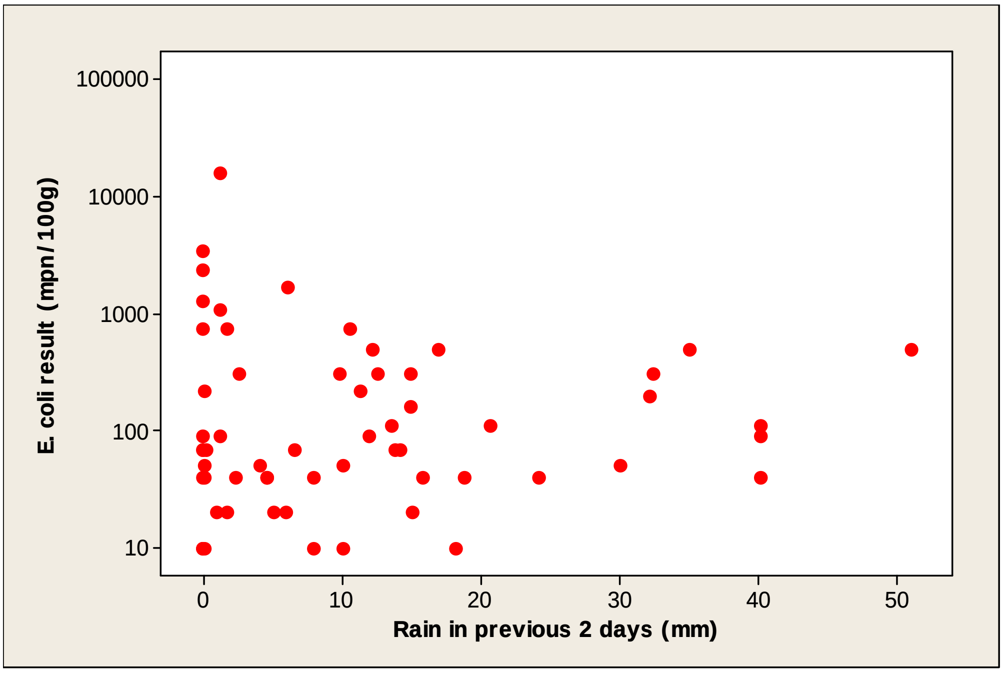


Figure 11.8 Scatterplot of result versus rainfall in previous 2 days (mussels)

No correlation was found between *E. coli* result in mussels and rainfall in the previous 2 days (Pearson correlation =0.067, p=0.608, Appendix 6).

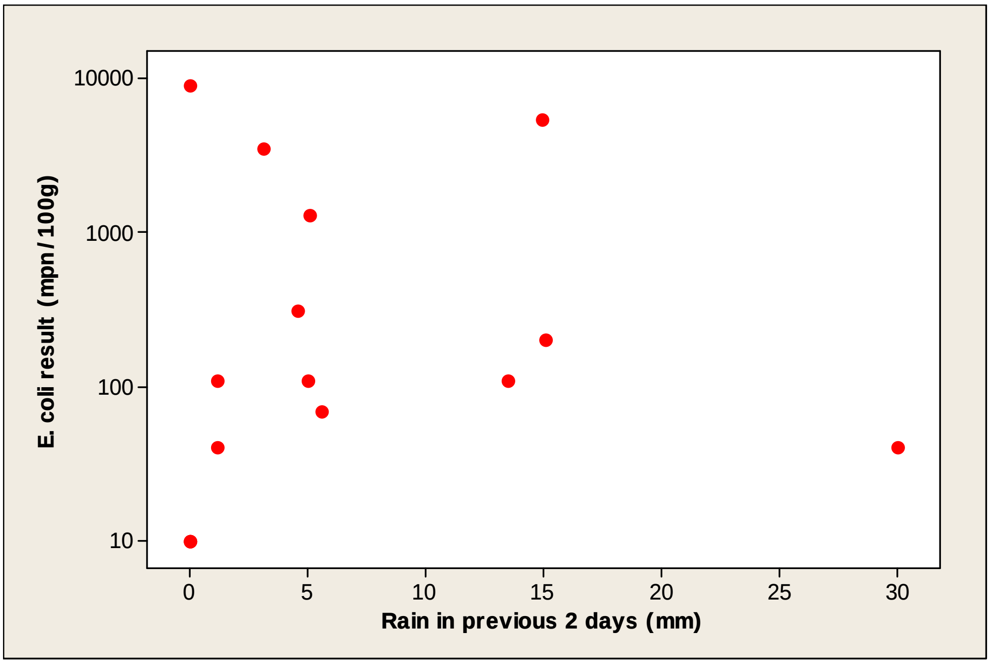


Figure 11.9 Scatterplot of result versus rainfall in previous 2 days (oysters)

No correlation was found between *E. coli* result in oysters and rainfall in the previous 2 days (Pearson correlation =0.311, p=0.260, Appendix 6).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above.

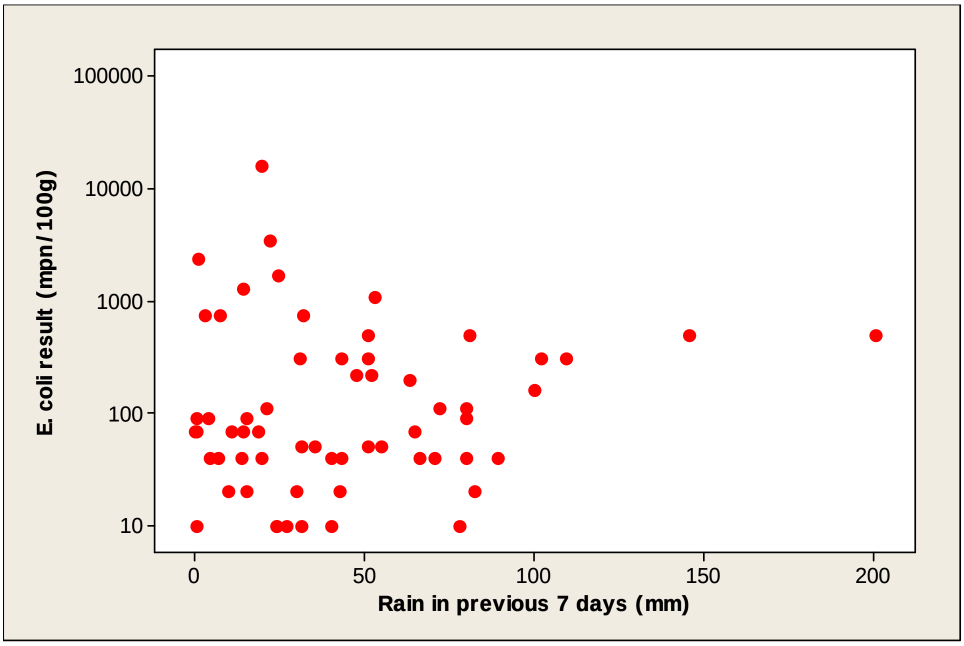


Figure 11.10 Scatterplot of result versus rainfall in previous 7 days (mussels)

No correlation was found between *E. coli* result in mussels and rainfall in the previous 7 days (Pearson correlation = 0.079, p=0.544, Appendix 6).

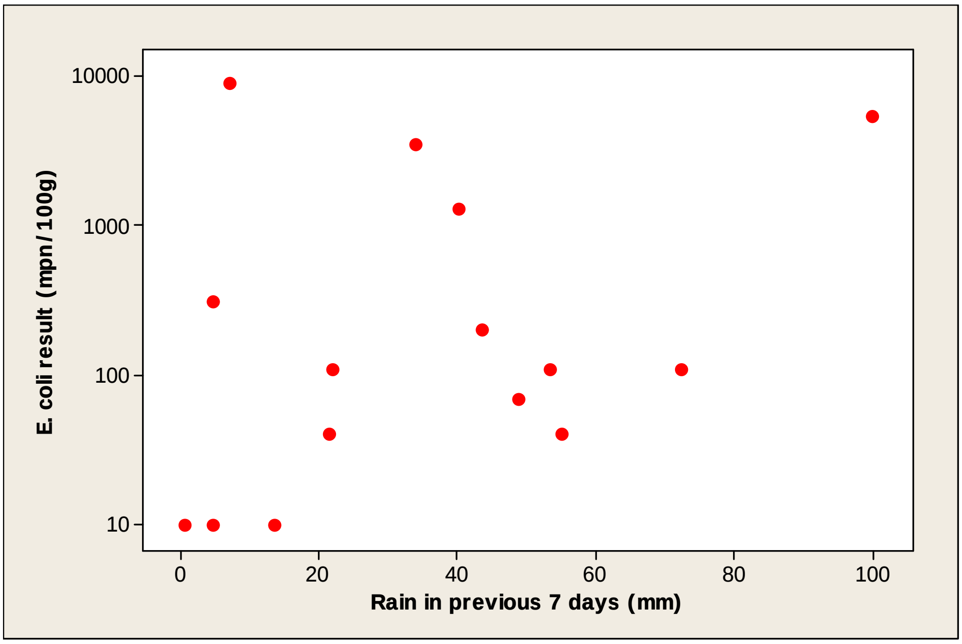


Figure 11.11 Scatterplot of result versus rainfall in previous 7 days (oysters)

No correlation was found between *E. coli* result in oysters and rainfall in the previous 2 days (Pearson correlation = 0.279, p=0.314, Appendix 6).

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figures 11.12 and 11.13 present scatterplots of *E. coli* results for mussels and oysters respectively by predicted height of the previous high water at Rubha A'Bhodaich (predictions from Totaltide tidal prediction software). It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

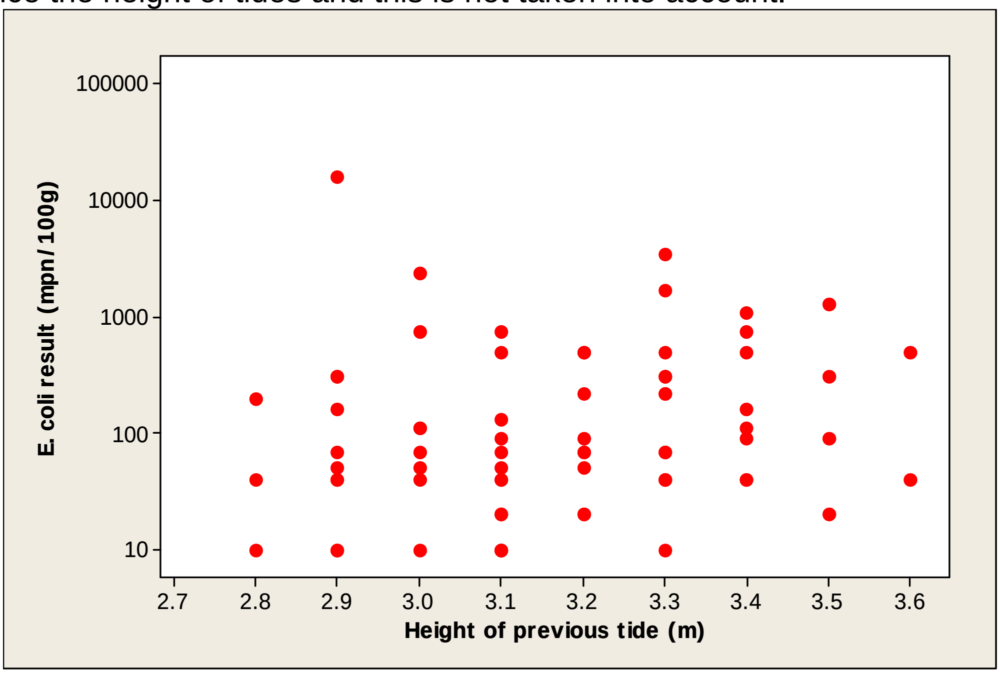


Figure 11.12 Scatterplot of result by tide size (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide for mussels (Adjusted R-sq=1.9%, p=0.130, Appendix 6)

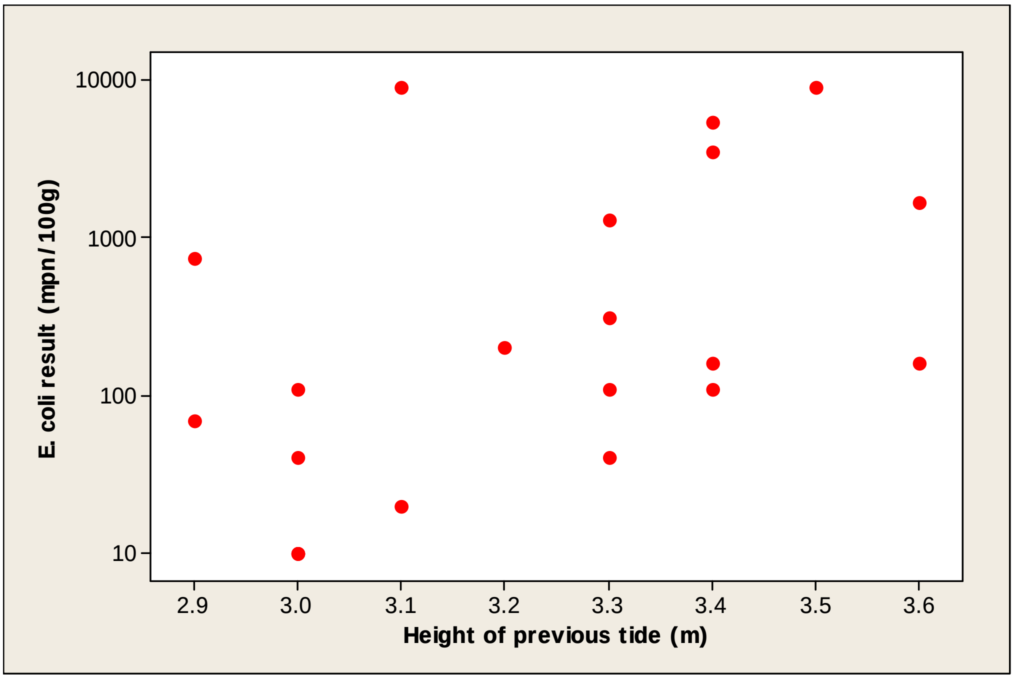


Figure 11.13 Scatterplot of result by tide size (oysters)

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result and predicted height of the previous tide for oysters (Adjusted R-sq=21.2%, p=0.021, Appendix 6).

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results.

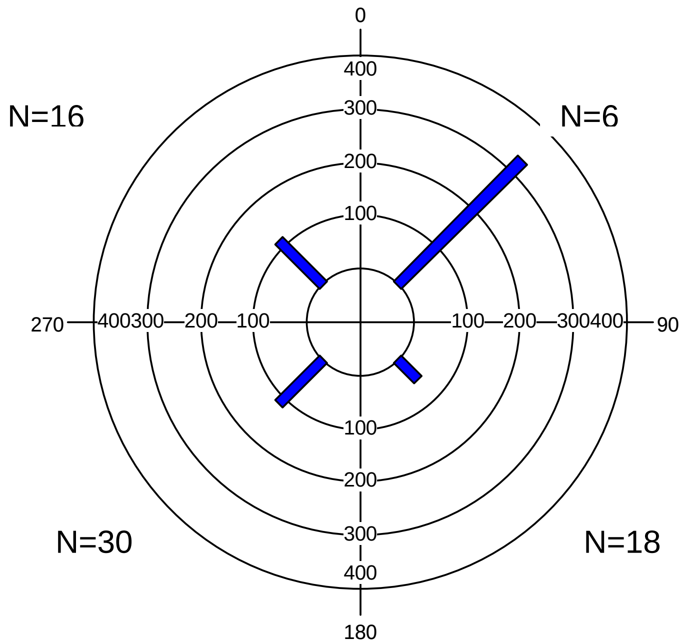


Figure 11.14 Circular histogram of geometric mean *E. coli* result tidal state (mussels).

High water is at 0 degrees, low water is at 180 degrees. No correlation was found between tidal state and *E. coli* result for mussels (circular-linear correlation, r=0.114, p=0.418, Appendix 6).

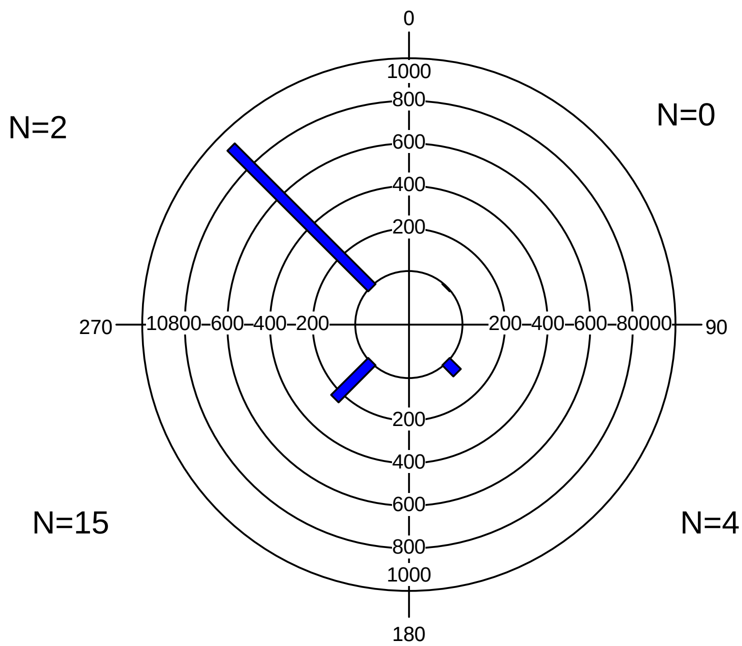


Figure 11.15 Circular histogram of geometric mean *E. coli* result tidal state (oysters).

High water is at 0 degrees, low water is at 180 degrees. No correlation was found between tidal state and *E. coli* result for oysters (circular-linear correlation, r=0.145, p=0.687, Appendix 6). It must be noted that sample numbers were low, and that the majority of samples were collected during the first half of the flood tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.16 presents a scatterplot of *E. coli* results against water temperature for mussels, Figure 11.17 presents the same for oysters.

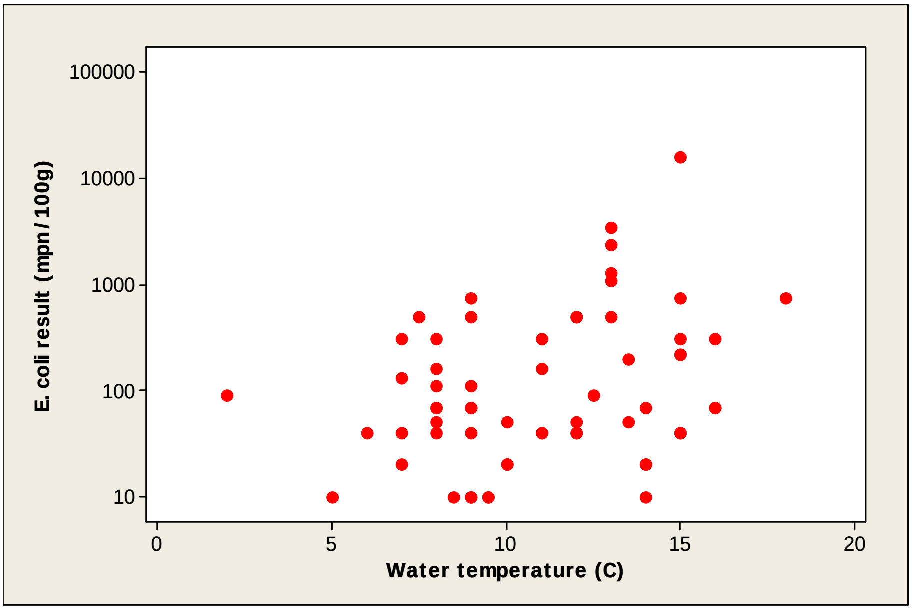


Figure 11.16 Scatterplot of result by water temperature (mussels)

The coefficient of determination indicates that there was an extremely weak positive relationship between the *E. coli* result and water temperature for mussels (Adjusted R-sq=8.4%, p=0.013, Appendix 6)

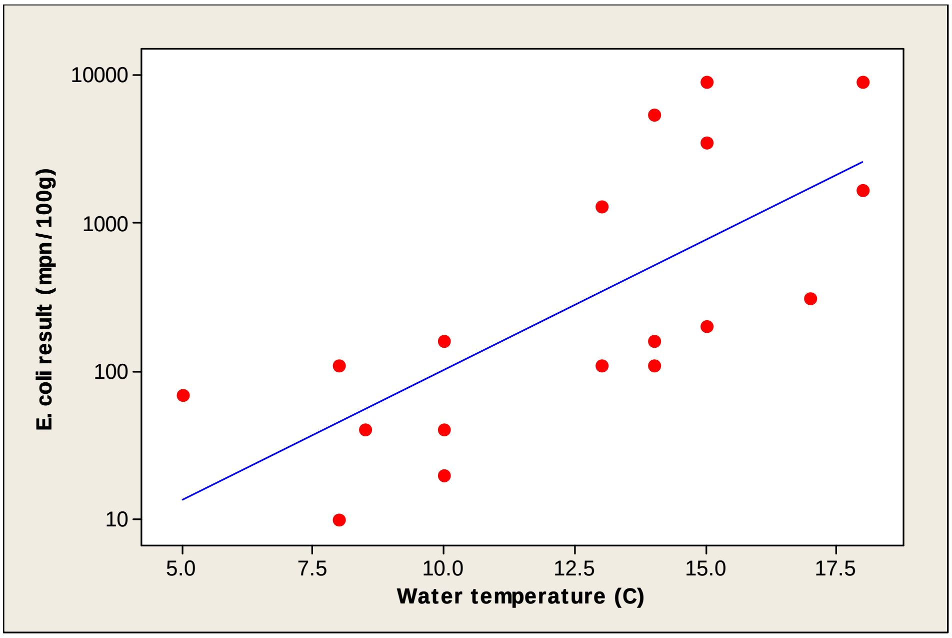


Figure 11.17 Result by water temperature (oysters) with best fit line

The coefficient of determination indicates that there was a positive relationship between the *E. coli* result and water temperature for oysters (Adjusted R-sq=48.4%, p=0.001, Appendix 6)

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production areas. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Glasgow: Bishopton weather station, and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.20 for mussels and 11.21 for oysters. As already noted, differences in local topography and distance mean it is likely that the patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time.

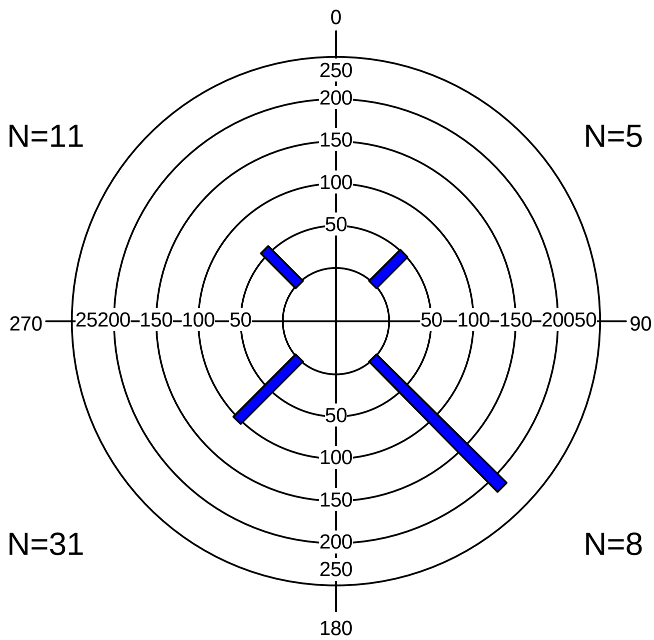


Figure 11.18 Circular histogram of geometric mean *E. coli* result by wind direction (mussels)

A weak correlation was found between wind direction and *E. coli* result for mussels (circular-linear correlation, r=0.243, p=0.047, Appendix 6). Mean results were highest when the wind was blowing from the south east.

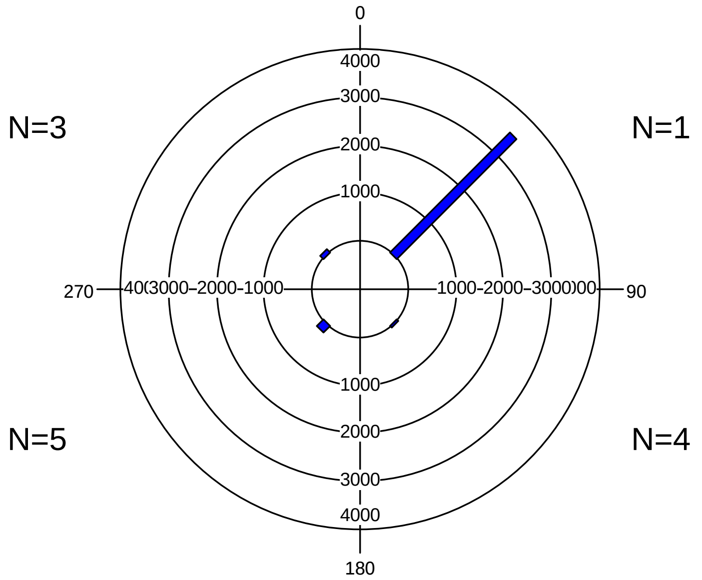


Figure 11.19 Circular histogram of geometric mean *E. coli* result by wind direction (oysters)

No correlation was found between wind direction and *E. coli* result for oysters (circular-linear correlation, r=0.316, p=0.366, Appendix 6). Sample numbers were very low.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.20 and 11.21 present scatter plots of *E. coli* result against salinity for mussels and oysters respectively, where salinity readings were available.

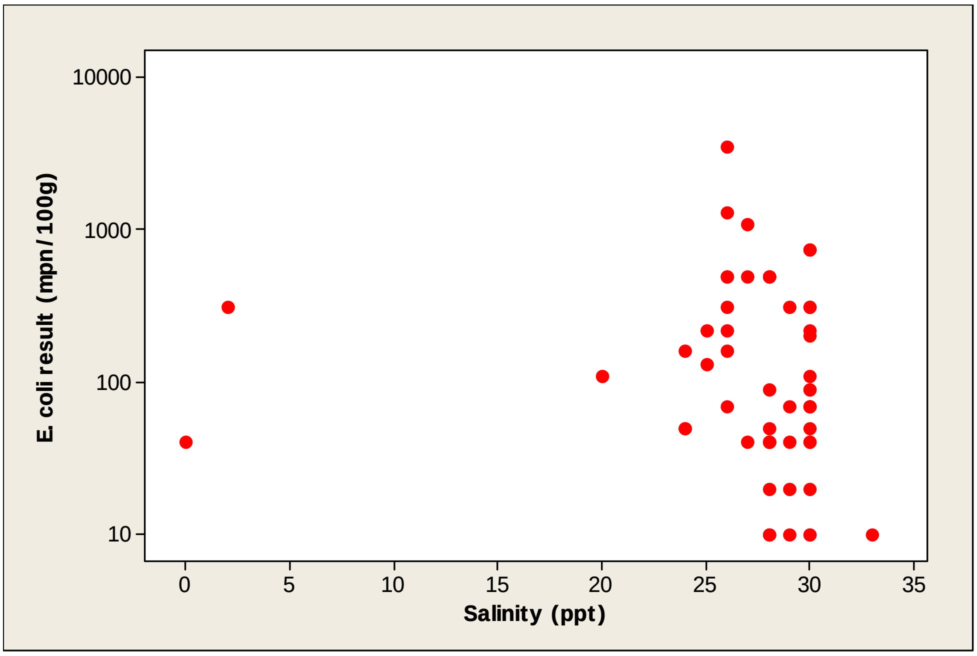


Figure 11.20 Scatterplot of result by salinity (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for mussels (Adjusted R-sq=0.0%, p=0.449, Appendix 6). Very low salinities were recorded for two samples taken from the Troustan site.

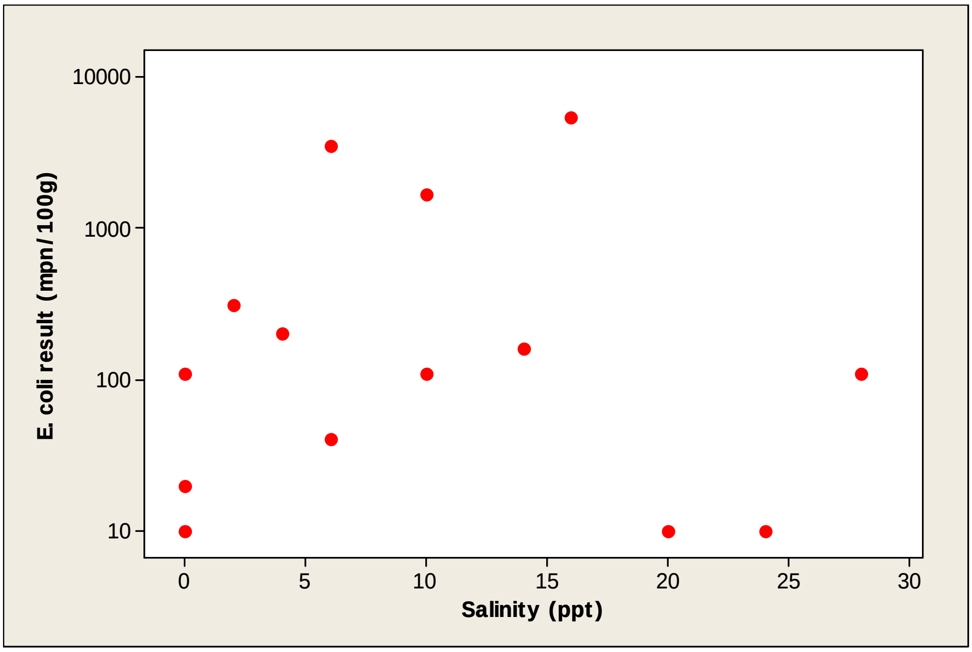


Figure 11.21 Scatterplot of result by salinity (oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for oysters (Adjusted R-sq=0.0%, p=0.857, Appendix 6). Salinities recorded were generally lower at this site, which is closer to the head of the loch, and thus main freshwater sources, than the mussel sites.

11.7 Evaluation of results over 4600 *E. coli* MPN/100g

Four results over 4600 *E. coli* MPN/100g were reported. Three of these were oyster samples taken from the Loch Striven site, and one was a mussel sample taken from the Troustan site. They were all taken between July and October while water temperatures were relatively warm. They were taken under varying tidal and meteorological conditions.

Table 11.2 Historic *E. coli* sampling results over 4600 MPN/100g

Collection date	*E. coli* result (MPN/ 100g)	Location sampled	Site	Species	2 day rainfall (mm)	7 day rainfall (mm)	7 day wind direction	Previous tide height (m)	Time since high water	Water temperature (ºC)
15/07/2002	9100	NS053822	Loch Striven	Oysters	*	*	*	3.5	6:57	15
02/08/2004	9100	NS053822	Loch Striven	Oysters	0	7.1	*	3.1	6:36	18
27/10/2004	5400	NS053822	Loch Striven	Oysters	14.9	99.9	205	3.4	9:55	14
10/07/2007	16000	NS073770	Troustan	Mussels	1.2	19.4	268	2.9	3:02	15

* Data unavailable

Monitoring results submitted for Troustan mussels subsequent to the initial drafting of this report showed an additional three results over 4600 MPN/100 g. These were 9100 MPN/100g on 15/01/2008, >18000 MPN/100g on 08/04/2009, and 9200 MPN/100g on 08/09/2009. None of these was taken during the summer. During 2008, only two samples exceeded the B class limit. Two of these were taken during periods when the water temperature would have been colder, however no further analysis was undertaken on these results.

11.8 Summary and conclusions

No shellfish samples were taken from the Fearna site. The geometric mean *E. coli* result was higher for oysters taken from the Loch Striven site than mussels taken from the Troustan site, and more results over 4600 were recorded in oysters from the Loch Striven site. As common mussels accumulate higher levels of faecal bacteria than do Pacific oysters, it might be expected that mussel samples collected from the same location as the oysters would have contained even higher concentrations of faecal bacteria. Within the Troustan site, several locations were sampled, and the results gave the impression of higher levels of contamination towards the southern end of the site, though this was not conclusive.

A seasonal effect was found, with mean results for both Loch Striven oysters and Troustan mussels significantly higher for the summer than those in the spring. Three of four results over 4600 *E. coli* MPN/100 g ocurred during the summer and all four occurred at water temperatures of 14 ºC or above. Positive relationships between *E. coli* results and water temperature were found for both species, although the relationship was very weak for mussels.

No relationships between *E. coli* results and recent rainfall or salinity at the time of sample collection were found. Salinities were lower on average at the Loch Striven oyster site, which is closer to the head of the loch.

A weak positive relationship between tide size (i.e. spring or neap) and *E. coli* result was found for Loch Striven oysters but not for Troustan mussels. This may be due to their location in relation to sources of contamination, as it implies that greater tidal transport distances result in higher levels of contamination impacting on the Loch Striven site. No influence of tidal state (i.e. high/low/ebb/flood) was found for either site/species.

A correlation was found between wind direction and magnitude of *E. coli* results for Troustan mussels only, with results higher on average when the wind was blowing from the south east, indicating that winds from this direction set up circulation patterns in the loch that direct contamination toward the site.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for this production area as it has held seasonal classifications for the last three years.

12. Designated Shellfish Growing Waters Data

The area considered in this report is also part of a shellfish growing water which was designated in 1998. The growing water encompasses a larger area than the two production areas covered by this report and also includes the Kyles of Bute. The extent of the growing water is shown on Figure 12.1.

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Twice yearly for metals in water
- Annually for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

Two points within the growing water were sampled for faecal coliforms in mussels. One of these was at the Loch Striven mussel/oyster raft, where two samples were taken in 2002/3. The other site was over 5 km to the south of the Troustan site, on the shore near the mouth of the loch. Monitoring results for faecal coliforms in shore mussels from 2002 to the end of 2007 have been provided by SEPA (faecal coliforms/100g). These results are presented in Table 12.1.

Table 12.1 Growing waters monitoring results

	Site	Loch Striven	Loch Striven
	OS Grid Ref.	NS 053 822	NS 09400 72400
2002	Q4	40	
2003	Q1	20	
	Q2	no result	no result
	Q3		24000
	Q4		90
2004	Q1		220
	Q2		40
	Q3		310
	Q4		10
2005	Q1		50
	Q2		950
	Q3		18000
	Q4		220
2006	Q1		380
	Q2		500
	Q3		>18000*
	Q4		250
2007	Q1		60
	Q2		no result
	Q3		no result
	Q4		no result

Assigned a nominal value of 36000 for statistical analysis

Only two samples were taken from the raft at the Loch Striven site (NS 053 822), and these both had very low levels of contamination. At the site near the mouth of the loch the geometric mean result was 402 faecal coliforms/100g, with some very high results obtained in quarter 3 of some years. A significant difference was found between results by quarter at this site, with results in quarter 3 significantly higher than those in quarters 1 and 4 (one-way ANOVA with Tukeys comparison, p=0.009, Appendix 6). This is a similar, but stronger pattern to that observed in the historical *E. coli* monitoring results for both rope mussels and Pacific oysters. The high results obtained in quarter 3 indicate that there are significant seasonal sources in close proximity to the sampling location, but these are not expected to have nearly so much impact on the fishery sites, the closest of which is 5 km from the sampling location.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as shellfish species, environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report.

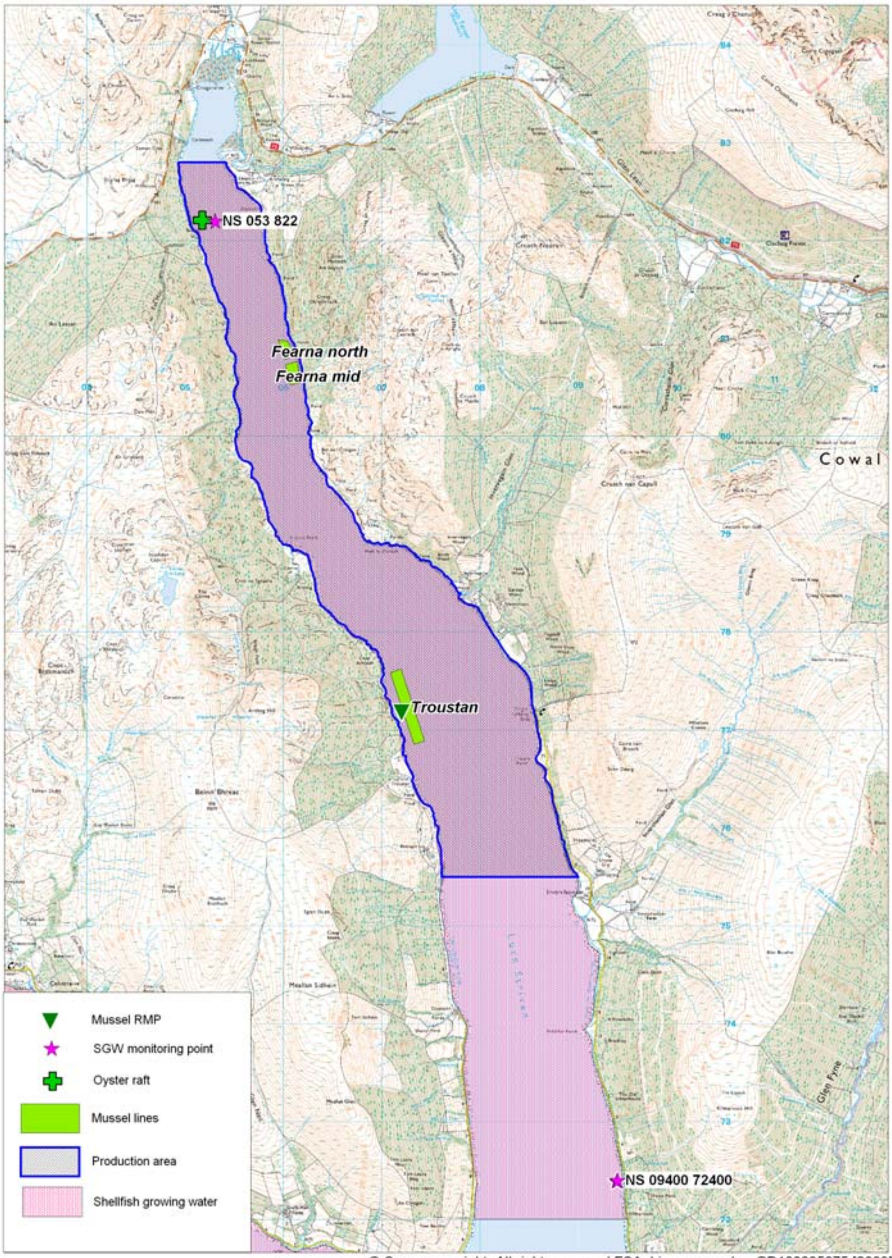


Figure 12.1 Designated shellfish growing waters

13. River Flow

There are no river gauging stations on rivers or burns discharging to Loch Striven. The following rivers and streams were measured and sampled during the shoreline survey. These represent the majority of the large freshwater inputs to Loch Striven, and other smaller inputs in close proximity to the mussel fisheries. A total of 77.3 mm of rain fell at Benmore in the 7 days prior to the survey, so discharge from these watercourses was likely to have been relatively high at the time of survey.

Table 13.1 River and stream loadings for Loch Striven

No	Grid Reference	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/day)	*E.coli* (cfu/ 100 ml)	Loading (*E.coli* per day)
1	NS 06209 80595	Stream	1.25	0.11	0.08	950	100	9.5E+08
2	NS 06143 80898	Stream	1.04	0.19	0.11	1900	<100	*
3	NS 06087 81005	Stream	1.07	0.16	0.057	840	<100	*
4	NS 07807 78385	Intervegain Burn	7.07	0.21	0.117	15000	100	1.5E+10
5	NS 07223 76737	Stream	0.95	0.08	0.156	1000	<100	*
6	NS 06998 77526	Stream	1.10	0.15	0.011	160	<100	*
7	NS 05485 84247	Balliemore Burn	7.60	0.46	0.473	140000	1100	1.6E+12
8	NS 05625 84125	Stream	2.20	0.09	0.26	4400	<100	*
9	NS 05781 82348	Stream	0.17	0.02	^	^	3100	^
10	NS 05570 82820	Glentarsan Burn	7.50	0.26	0.114	19000	34	6.5E+09

* Loading not calculated
^ Stream running through pipe, flow too small to calculate loading

Loch Striven receives water from a catchment area of approximately 68 km^2 (not including the loch itself), which is mainly a mixture of managed forestry or woodland and steeply sloping rough hill land.

The most significant of the watercourses is the Balliemore Burn, which discharges to the head of the loch and contributed the majority of the runoff-borne loading carried by the streams measured during the survey (1.6 x 10^{12} *E.coli* / day, roughly equivalent to septic tank discharge from a population of 200). Balliemore Burn is bordered by areas of improved pasture in its lower reaches, and mainly by coniferous woodland in its upper reaches.

Another two larger streams were recorded (Invervegain Burn and Glentarsan Burn), which had daily flows approximately one-tenth that of the Balliemore Burn, but much lower levels of *E. coli*. The Invervegain Burn drains an area of coniferous woodland. The Glentarsan Burn also mainly drains coniferous woodland, and has the Loch Tarsan reservoir within its catchment, which will buffer water levels in this burn to some extent.

None of these three burns discharge in close proximity to any of the mussel sites, but overall it is expected that there will be a greater freshwater influence nearer the head of the loch, and the more contaminated of these (the Balliemore Burn) may result in higher levels of contamination arising here as well.

In addition to these larger burns, the Loch Striven power station outflow at the head of the loch was sampled, and contained 100 *E. coli* cfu/100ml, but it was not possible to safely measure this watercourse. As it was of a similar size to the Balliemore Burn, and much less contaminated, this watercourse is likely to be of considerably less importance than the Balliemore Burn.

Streams 1, 2 and 3 discharge adjacent to the Fearna sites, and were all small streams with low levels of *E. coli* (100, <100 and <100 cfu/100ml respectively). Streams 2 and 3 drain forested areas, and stream 1 drains a mixture of forest and open hill land. On this basis, stream 1 at the south end of the Fearna sites may be a slightly more significant source of contamination than streams 2 and 3.

A few small streams draining areas of forest discharge to the shore adjacent to the Troustan site. Two of these were measured and sampled during the shoreline survey (streams 5 and 6), and both were small and had low levels of *E. coli* (<100 cfu/100ml). The Troustan Burn, which was not measured or sampled has a slightly larger catchment area than streams 5 and 6 discharges about 400 m to the south of the Troustan site, and had livestock grazing its banks in its lowest reaches, so may carry a more significant *E. coli* loading.

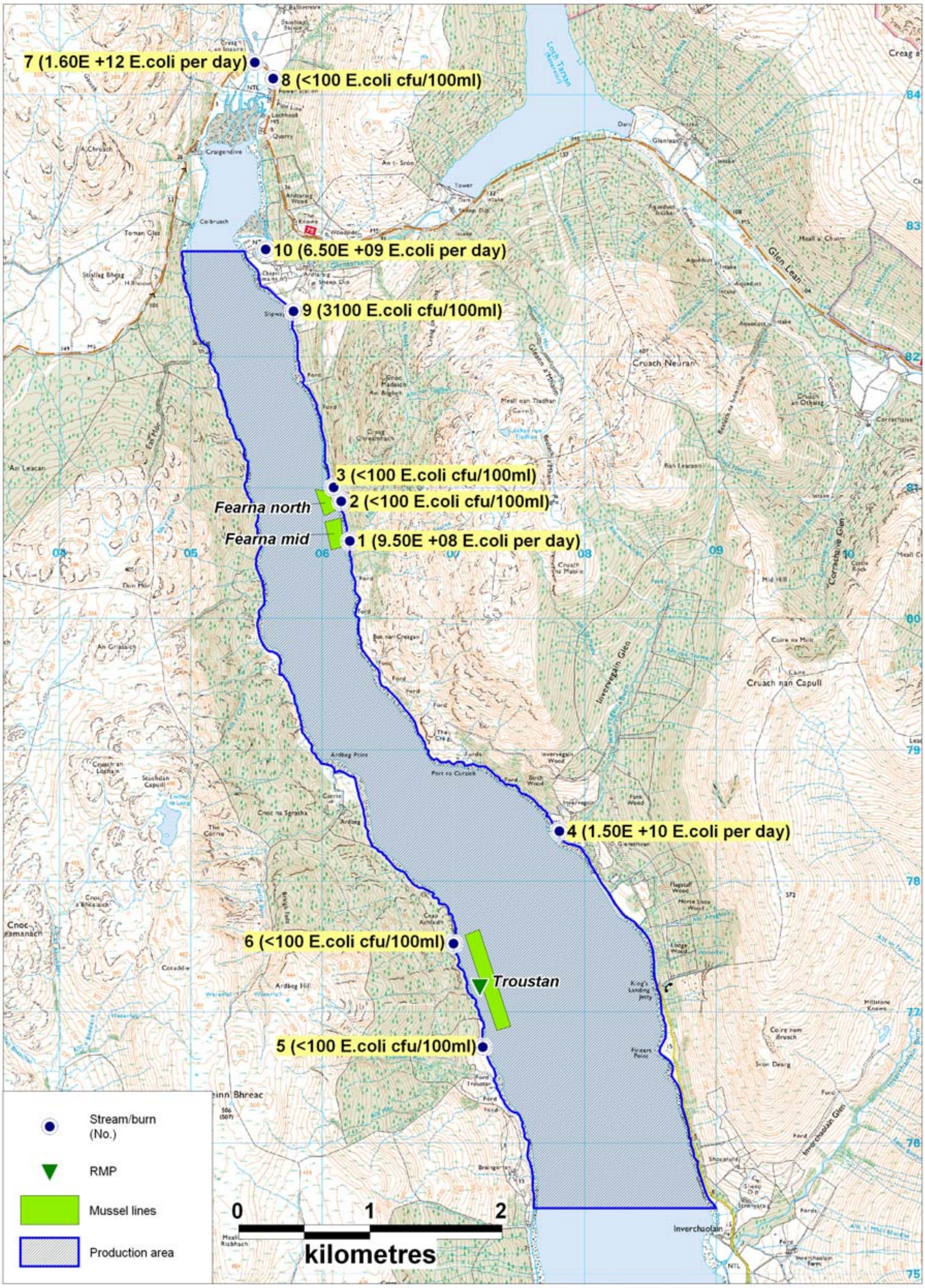
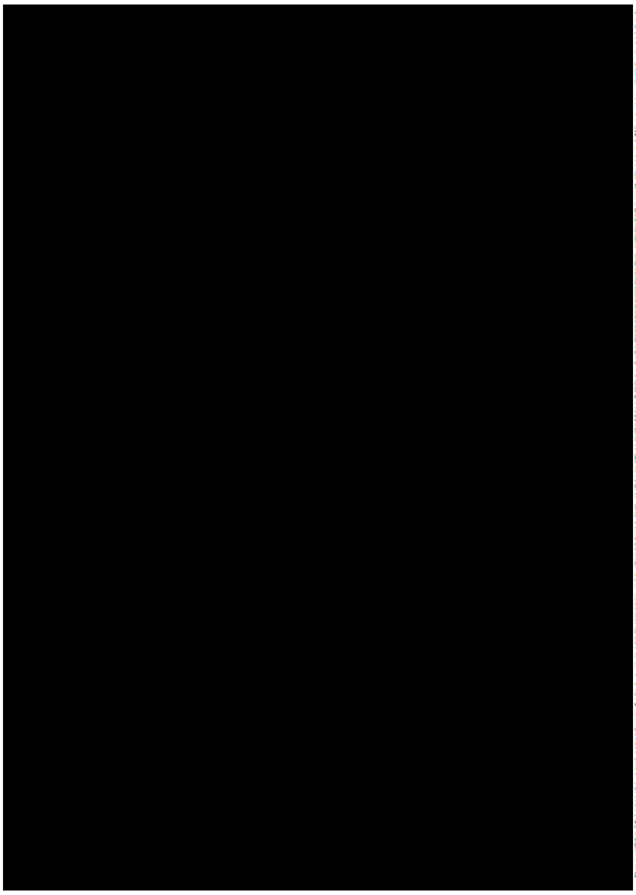


Figure 13.1 Significant streams and loadings

14. Bathymetry and Hydrodynamics



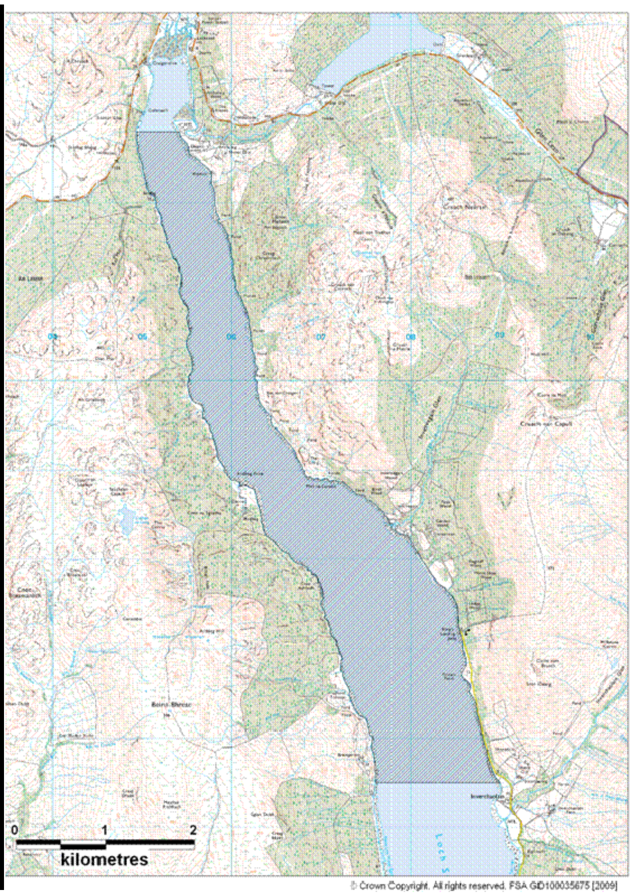


Figure 14.1 Bathymetry of Loch Striven
Figure 14.2 Loch Striven

Loch Striven is long and narrow, as shown in Figures 14.1 and 14.2, with a length of 12.9 km and a maximum depth of 69 m, no sills and only small intertidal areas. Depth increases sharply from the shore, particularly at the southern end of the production area where it is over 50 m deep within 200 m of the shore. It has a total area at high water of 12.8 km^2, and a mean depth at low water of 40 m (Edwards and Sharples, 1986).

Tidal Curve and Description

The two tidal curves below are for Rubha A'Bhodaich. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 08/10/08 and the second is for seven days beginning 00.00 GMT on 16/10/08. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

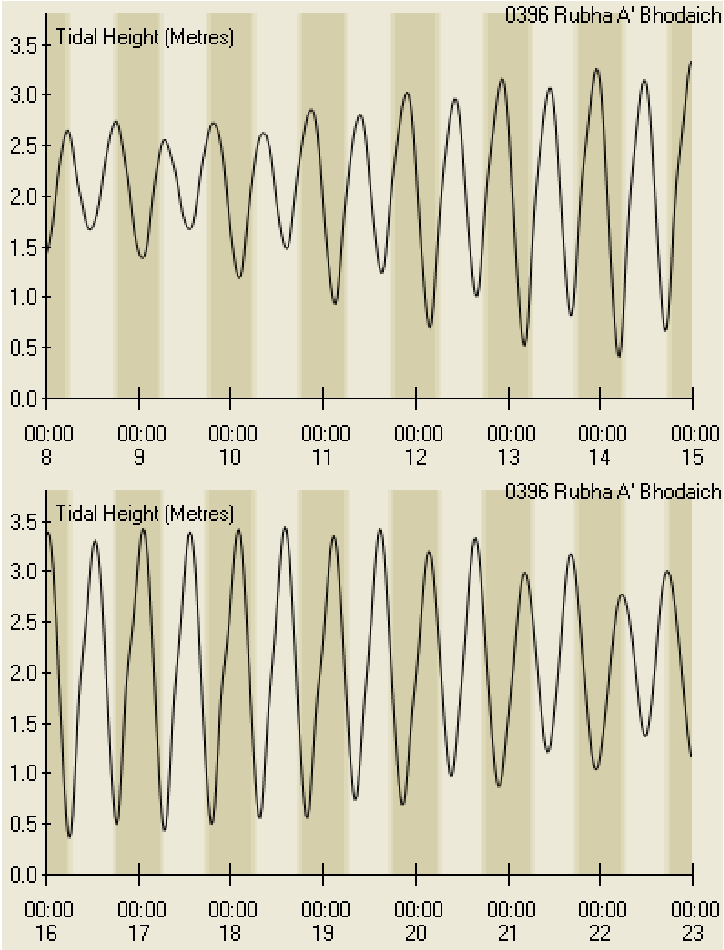


Figure 14.3 Tidal curves for Rubha A' Bhodaich

The following is the summary description for Rubha A' Bhodaich from TotalTide: Rubha A' Bhodaich is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal. Predicted heights are in metres above Chart Datum.

MHWS	3.2 m
MHWN	2.7 m
MLWN	1.2 m
MLWS	0.5 m

The tidal range at spring tide is therefore approximately 2.7 m and at neap tide 1.5 m.

Currents

No current data was available for Loch Striven. Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The tidal range here is fairly large, so tidally driven exchange of water is likely to be relatively important. Tidally driven currents within the loch would be expected to move in a northerly direction on the flood tide, and a southerly direction on the ebb tide back along a similar path. Therefore, sources of contamination discharging to the east and west shores may be expected to impact in a region to the north and south of the source, with greater impacts closer to the source. The size of this region will depend on the strength of tidal flows, which are uncertain, but will be larger on spring tides. As the loch is long, narrow and relatively deep, tidal exchange of water is likely to be fairly slow, and this is reflected in the relatively long flushing time of 12 days (Edwards and Sharples, 1986).

The loch is located in a steep sided glacial valley with a north-south aspect. The surrounding hills rise to over 600 m in places. Therefore, it will receive some shelter from winds from most directions, but is more open to southerly or northerly winds, which would be funnelled up or down the Loch by the surrounding land. Wind-driven currents have the potential to significantly alter flows around the production area, creating surface currents which flow in the same direction as the wind. However, these are probably of less overall importance than tidally driven circulation.

The catchment area of Loch Striven is relatively small at about 68 km^2 which is drained by several burns and numerous smaller streams. An average salinity reduction of 0.3 ppt was calculated on the basis of tidal and freshwater inflows indicating relatively low freshwater influence (Edwards and Sharples, 1986) although this will fluctuate depending on rainfall. Salinitiy profiles taken during the shoreline survey indicated that there was some freshwater influence and stratification in places. Suprisingly, the two highest surface salinities were recorded closest to the head of the loch at the Loch Striven and Fearna sites (29.3 and 29.8 ppt respectively). All other profiles were taken further away from the head of the loch in the vicinity of the Troustan site where surface salinities ranged from 24.2 to 27.4 ppt. The shoreline survey followed a relatively wet week. Salinity readings taken at the Troustan site during *E. coli* classification monitoring ranged from 0 to 33 ppt, averaging 27 ppt. Salinity readings taken at the Loch Striven site during *E. coli* classification monitoring ranged from 0 to 28 ppt, averaging 10 ppt, suggesting a much higher freshwater influence nearer the head of the loch. Therefore, freshwater (density) driven currents are likely to be of significance in Loch Striven at times, particularly towards the head of the loch. Simplistically, a net seaward flow of fresh water will occur at the surface of the Loch, possibly with return currents of more saline water at depth. This may to some extent constrain the movement of contamination from sources to the south of the production area towards the fishery.

Conclusions

Tidal influences will result in a north / south flow of water in the loch as the tide floods and ebbs. This will therefore create a region of impact to the north and south of sources discharging to the shore, with greater impacts closer to the source. Freshwater inputs will result in a net southerly flow of less saline water on the surface, which may carry relatively high levels of contamination. Freshwater influence and hence levels of freshwater borne contamination may be greater towards the head of the loch, although this was not apparent from measurements taken during the shoreline survey. Superimposed on this, wind driven currents may significantly alter water movement patterns within the loch at times through the creation of surface currents moving in the direction of the wind, which is likely to mainly align along the north south axis due to local topography.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 14th and 15th October 2008. A total of 77.3 mm of rain fell at Benmore in the 7 days prior to the survey, of which 41.4 mm fell on the 9th October.

Both the Troustan and Fearna sites consist of longlines with a system of continuous rope ladders strung in loops to a depth of 8 metres. Harvest is rotational within the sites and 10 long lines are typically harvested from each site each year. Fearna has two blocks consisting of 10 long lines and Troustan has three blocks. Harvesting typically takes place between November and May. Additionally, there was an oyster raft towards the northern end of the production area, but this was not in commercial production.

Three private sewer pipes to the east shore were observed, all between 1 and 1.5 km from the Troustan site, and between 2 and 4 km away from the Fearna sites. One of these was observed actively discharging at the Keeper's Cottage and a seawater sample taken from adjacent to the discharge contained >10000 *E. coli*/ 100ml, confirming that it was a foul discharge. There was a toilet on the service raft at the Troustan mussel farm. This discharged directly to the water below the raft. The raft is moved around the farm as work is undertaken and so this represents a non-fixed point source that would be located on or very near the shellfish lines.

Land use surrounding Loch Striven was predominantly forestry with some pasture. 20 cattle were observed in a pasture on the western side of the loch near Troustan. At the head of the loch, 29 sheep were observed grazing on pasture adjacent to the burn. Sheep were also observed on the Ardtaraig Estate. The Glenstriven Estate hosts hunting parties in the autumn and pheasants numbering in the hundreds were observed in most open areas around the loch. Over 100 cormorants and gulls were observed resting on the floats at the Troustan site.

Some of the cottages on the estates are let to summer visitors, but it is the autumn hunting season that sees the highest number of visitors to this area. Even so, local information indicated that generally no more than 15-20 hunters would be expected any given weekend during the season.

Boating activity in the immediate vicinity of the shellfishery was limited to two small work boats and one fishing boat.

Seawater samples generally had levels of *E. coli* consistent with class B waters, ranging from 10 to 88 cfu/100ml, with two exceptions. 380 *E. coli* cfu/100ml were found in a seawater sample taken at the Troustan mussel lines. The source of contamination at this location was not clear, though the >10000 *E. coli* cfu/100ml were found in a seawater sample taken adjacent to an actively discharging sewer pipe on the east shore. No correlation was found between *E. coli* concentration and salinity (Pearson correlation=-0.168, p=0.621, Appendix 6, the sample yielding >10000 *E. coli* cfu/100ml omitted from analysis as it was taken at the end of an active discharge and so was not representative of broader contamination levels in the area).

Mussel samples taken from the Fearna sites contained from 50 to 1100 *E. coli* MPN/100g, with a geometric mean of 259 *E. coli* MPN/100g. Results were markedly higher at the surface for the sample taken nearest the shore (1100 *E. coli*) than those taken from deeper within the water column or from the other sample point located further from the shore.

Mussel samples taken from the Troustan site the contained from 110 to 1700 *E. coli* MPN/100g. Here again, the surface sample taken from near to shore contained a higher concentration of *E. coli* (1300) than the two deeper samples taken from the same location. Samples taken further from shore contained relatively high *E. coli* concentrations throughout the water column. This location also showed high levels of contamination in the seawater, which is consistent with the high results found in the mussels. However the source of this contamination is not clear. There were men working on the Troustan site at the time of survey, and the service barge was located inshore and slightly north of the sampling location and so the toilet may have been a source.

It was not possible to be certain about the exact depth the samples were taken from due to the rope system used.

All larger burns were measured and sampled, together with some of the smaller streams which were in close proximity to the fisheries. *E. coli* levels in the streams sampled ranged from 34 to 3100 cfu/100ml. The largest of these streams, Balliemore Burn, which also contributed by far the highest loading of the streams measured in terms of *E. coli* per day, discharges into the north end of the loch.

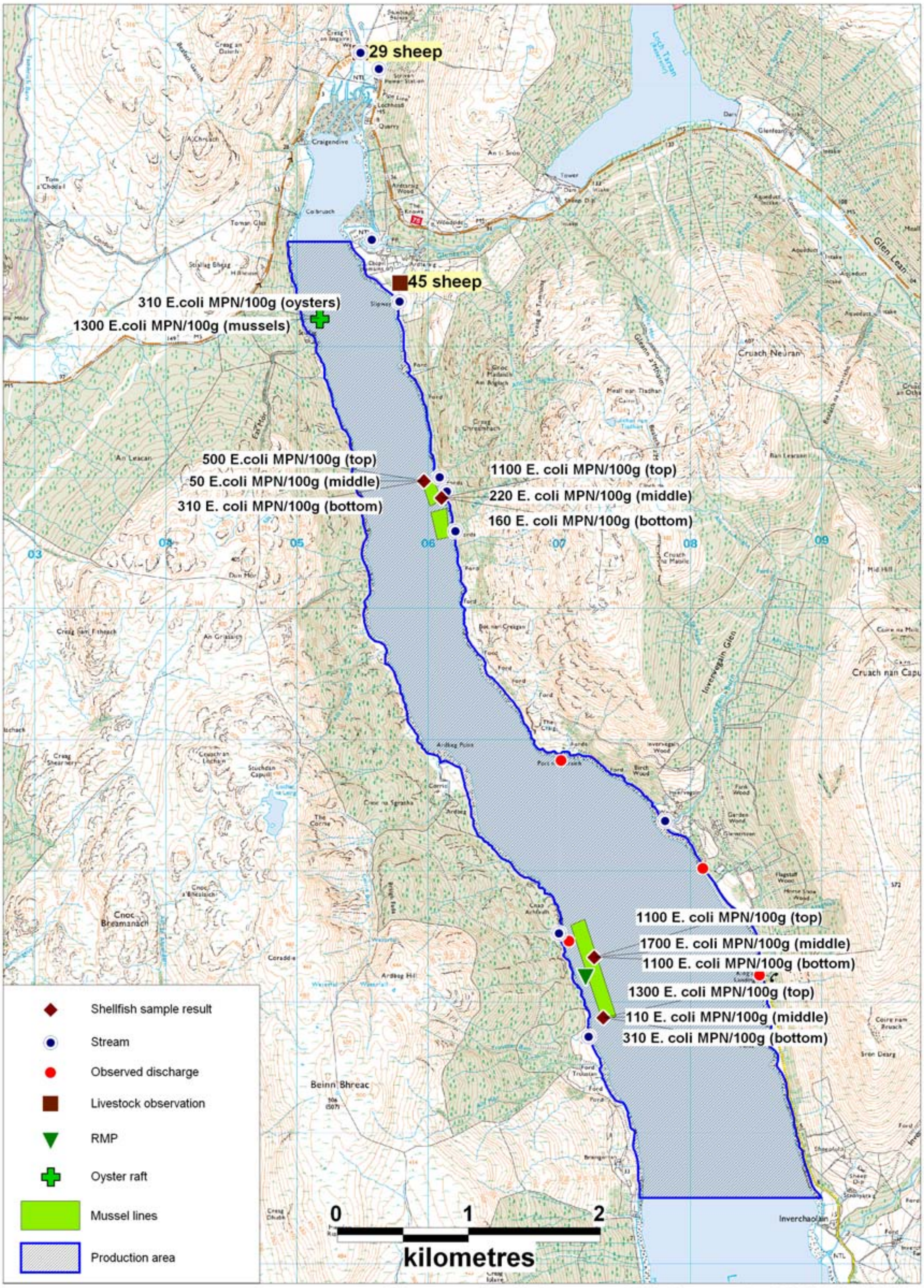


Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

Five small private discharges to Loch Striven were identified as part of this survey. Three were directly observed on the east shore towards the southern end of the production area, all between 1 and 1.5 km from the Troustan site, but on the opposite shore. They were between 2 and 4 km south of the Fearna sites and on the same shore. The fourth was a SEPA-registered septic tank discharge to the head of the loch from the power station, which is about 3 km north of the Fearna sites. All of these discharges are relatively fixed in location. An estimate of the total population equivalents discharging to Loch Striven from these discharges is about 20. None are in close proximity to the classified fisheries, and so overall impacts from these discharges is expected to be minor at both the Troustan and Fearna sites.

The fifth discharge noted in the area is on the barge servicing the mussel farm, which has an on-board toilet which discharges directly below it when used. If the toilet is used when the barge is near to the mussel lines, it could introduce pathogens directly to the fishery leading to localized impacts. By definition, the barge will be near the mussel lines when the toilet is likely to be in use. The discharge overboard of faecal waste into or near a shellfish harvesting area is not consistent with good sanitary practice. This practice poses the single most significant risk to the microbiological quality of mussels grown on these sites. The impact will be difficult to predict spatially or temporally as the barge will be moved around the site as work in carried out. Impacts are most likely to occur during maintenance works and harvesting, in the areas being serviced or harvested, so this source cannot adequately be accounted for in the sampling plan. As faecal contamination is likely to occur during harvesting, this is of serious concern. The harvester is advised to provide alternative arrangements for toileting (ie. holding tank or portable toilet) and to ensure that faecal wastes are not discharged from any barge or workboat in the vicinity of the mussel lines.

A sample taken from the oyster raft during the shoreline survey tested positive for both norovirus genogroups 1 and 2, indicating the presence of human faecal contamination in water surrounding the raft. The source of this was not immediately evident, though potential sources were septic tanks associated with the Striven Power Station and the Ardtaraig estate at the head of the loch.

During 2009, 6 container ships were mothballed at the southern end of the production area. The ships have on-board sewage treatment facilities sufficient for the crew permanently stationed aboard and for the planned temporary use as a venue for filming of a television program. So long as the onboard plants are functioning properly, no impact is anticipated at the fishery. However, should partially treated or untreated waste be discharged, this would impact the southern end of the Troustan mussel site in the first instance.

Agricultural impacts

Agricultural census data indicate that local agriculture is dominated by sheep production, with poultry, cattle and horses and ponies also farmed locally. The majority of the land surrounding Loch Striven is forest and rough hills, but there are some areas of pasture. At the time of shoreline survey, 29 sheep were observed grazing on pasture adjacent to the Balliemore burn, and a further 45 sheep were observed at the Ardtaraig Estate. Most of the land suitable for grazing is near the head of the loch or on hills well above the shoreline. However, 12 sheep were observed at Troustan, less than 500 m to the south of mussel farm. As the area is rough grassland rather than improved pasture, it is expected that livestock will move about large ranges and the animals observed during the survey are unlikely to be present in those locations for extended periods.

It is likely that while Troustan may be impacted by faecal waste from the small area grazed to the south, the grazing north of Fearna may receive greater levels of deposition due to the larger number of animals it supports. Any impact to either is likely to be seasonally variable as the livestock population expands in spring and spreads out across grazing areas, then contracts in late autumn as young animals are sent to market and remaining stock is brought down off the hills.

The Glenstriven Estate hosts a pheasant shoot, and over 150 pheasants were observed on the east shore of the loch during the shoreline survey. Numbers of these birds will be highest through the summer and early autumn, dropping off through the autumn and winter to low numbers in springtime. Contamination from these birds will mainly be carried to the production are via streams draining wooded areas on the east shore, which would be most likely to impact the Fearna site.

Wildlife impacts

The most likely wildlife sources of faecal contamination to the fisheries at Loch Striven are gulls, ducks and other waterbirds, deer, and seals. Gulls may be a significant source of contamination as they were observed resting on the mussel floats during the shoreline survey. A seal was also observed resting on the mussel lines so seals may cause significant localised impacts. Impacts from eider ducks may be expected to be higher during the winter and spring at the Fearna site as at the time of shoreline survey it had not yet been fitted with anti predator netting.

Deer are likely to be present in significant numbers, particularly in the wooded areas lining both sides of the loch. Any faecal contamination contributed by deer is most likely to be carried to the loch via streams draining wooded areas.

Of these impacts, there is no evidence to suggest that the majority will impact more heavily on any one particular area. The exception is the eider ducks, which may have a greater impact at the Fearna sites during the winter and spring until anti predator netting is installed.

Seasonal variation

Some of the cottages on the estates are let to summer visitors, but it is the autumn hunting season that sees the highest number of visitors to this area. Even so, generally no more than 15-20 hunters would be expected any given weekend during the season, which runs from October to February.

Livestock numbers are likely to be higher in the summer, so inputs from livestock may be higher during the summer, particularly following high rainfall events. Livestock are likely to access watercourses to drink more frequently during warmer weather.

Weather is wetter and windier during the winter months, so more rainfall dependent contamination such as runoff from woodland and pastures may be expected during these times.

An analysis of historic *E. coli* monitoring data showed a significant seasonal effect, with mean results for both Loch Striven oysters and Troustan mussels significantly higher for the summer than those in the spring. Three of four results over 4600 *E. coli* MPN/100g ocurred during the summer and all four occurred at water temperatures of 14 ºC or above. Positive relationships between *E. coli* results and water temperature were found for both species, although the relationship was very weak for mussels. This suggests that either inputs are higher in summer and/or the uptake of bacteria by the oysters is higher in warmer water. A similar, but stronger seasonal effect was found in shellfish growing waters monitoring data from shore mussel samples taken near the mouth of the loch, over 5 km from any of the fisheries.

In conclusion, there is likely to be more contamination of livestock (sheep/cattle) origin during the summer months as livestock numbers are likely to be higher at this time. Pheasant numbers are likely to be highest during the summer and early autumn. There is little in the way of tourism in the area, although small numbers of visitors may be expected in the summer and during the shooting season during the autumn. Analysis of historical *E. coli* monitoring data shows highest levels of contamination in the shellfish during the summer months.

Rivers and streams

Loch Striven receives runoff from a catchment area of approximately 68 km^2, which is mainly a mixture of managed forestry or woodland and steeply sloping rough hill land. The most significant of the watercourses measured and sampled during the shoreline survey was the Balliemore Burn, which discharges to the head of the loch, and is bordered by pastures in its lower reaches. It contributed the majority of the runoff borne loading carried by the streams measured during the survey (1.6×10^{12} *E. coli* / day, roughly equivalent to septic tank discharge from a population of 200). Another two larger streams were measured (Invervegain Burn and Glentarsan Burn), which had similar discharges to the Balliemore Burn, but much lower levels of *E. coli*. None of these three burns discharge in close proximity to any of the mussel sites, but overall it is expected that there will be a greater freshwater influence nearer the head of the loch, and the more heavily contaminated of these (the Balliemore Burn) may cause higher levels of contamination towards the northern end of the production area.

Three small streams discharge adjacent to the Fearna sites, and all carried low levels of contamination, although the stream at the southern end was slightly more contaminated than the other two. A few small streams draining areas of forest discharge to the shore adjacent to the Troustan site. Two of these were measured and sampled during the shoreline survey, and both were small and had low levels of *E. coli*. The Troustan Burn, which was not measured or sampled has a slightly larger catchment area the two measured streams discharges about 400 m to the south of the Troustan site, and had livestock grazing its banks in its lowest reaches, so may carry a more significant *E. coli* loading, and so contamination at this site may be higher at the southern end.

Meteorology, hydrology, and movement of contaminants

The tidal range here is fairly large, so tidally driven exchange of water is likely to be relatively important. Tidal influences will result in a north / south flow of water along the shore of the loch as the tide floods and ebbs. This will therefore create a region of impact to the north and south of sources discharging to the shore, with greater impacts closer to the source. The only sources discharging to the shore within 1 km of either the Troustan or Fearna sites are small streams. A weak positive relationship was found between tide height (i.e. spring or neap) and *E. coli* result for Loch Striven oysters, but not for Troustan mussels, suggesting that the oyster site may be close to the edge of the region of impact of an important source of contamination, possibly the Balliemore Burn at the head of the loch. No influence of tidal state (i.e. high/low/ebb/flood) was found for any of the sites.

The loch is more open to southerly or northerly winds, which would be funnelled up or down the Loch by the surrounding land. However, at Loch Striven, wind driven currents are probably of less overall importance than tidally driven circulation. A correlation was found between wind direction and magnitude of *E. coli* results for Troustan mussels only, with results higher on average when the wind was blowing from the south east. This site is nearer mouth of the loch and so is more open to winds from this direction than the Fearna site. The results imply that sources to the south east of this fishery may be of importance, although potential sources southeast of the production area boundary were not specifically investigated as part of the survey. Alternatively, winds from this direction may be acting to constrain the dispersion of contaminants from sources near the Troustan site.

The catchment area of Loch Striven is relatively small the reported average salinity reduction of 0.3 ppt indicates relatively low freshwater influence. Freshwater (density) driven currents will result in a net southerly flow of fresher water at the surface of the Loch, which may carry relatively high levels of contamination from sources such as the Balliemore Burn. This effect should be stronger following heavy rainfall, but on the basis of the predicted freshwater influence, is likely to be generally weak. Simplistically, this effect will move contamination from the most important source identified, the Balliemore Burn, in the direction of the fisheries, with those closest to the head of the loch most heavily impacted.

Salinity profiles taken during the shoreline survey indicated that there was some freshwater influence. The two highest surface salinities were recorded closest to the head of the loch at the Loch Striven and Fearna sites. Salinity readings taken during *E. coli* classification monitoring averaged 27 ppt at the Troustan site, and 10 ppt at the Loch Striven oyster site, suggesting a much higher freshwater influence nearer the head of the loch, a very different pattern to that observed during the shoreline survey. The surface salinity recorded at the Loch Striven site at the time of the shoreline survey was higher than that recorded on any of the 14 occasions when salinity was recorded here during *E. coli* classification monitoring. This discrepancy was unexpected, especially given that fairly high rainfall preceded the shoreline survey. However, the salinity recorded at this site during the survey was corroborated by laboratory testing of a water sample from the same site, which gave a result within 1ppt of that recorded in the field. The pattern of salinities observed during *E. coli* classification monitoring implies that there are probably significant differences in freshwater influence between the head of the loch and areas further south and therefore possibly in levels of contamination between the Troustan and Fearna sites. However, these salinity readings from the oyster site were taken from 2002 to 2004, before the start of the Official Control samplers, and there is no way of confirming their accuracy.

No relationship between historical *E. coli* monitoring results and recent rainfall or salinity at the time of sample collection was found at either the Loch Striven or Troustan sites, so although it may be anticipated that in general more contamination enters the production area via land runoff during wet weather, this does not appear to result in greater contamination in shellfish. It is not known for certain at what depth oysters sampled from the Loch Striven site were grown, however as they are suspended from a raft, it is likely that the salinity at the depth they were grown would have differed from that recorded at the surface. During the shoreline survey, higher *E. coli* levels were found in samples taken at the surface than in those taken at depth, indicating that contamination levels were higher in water at the surface.

No correlation was found between salinity and levels of *E. coli* found in water samples taken during the shoreline survey. Therefore, even if there is a higher freshwater influence at the Fearna sites than at the Troustan site, there is little evidence to suggest that this would result in marked differences in the levels of contamination in mussels.

Temporal and geographical patterns of sampling results

Historical *E. coli* classification monitoring data was available for the Troustan and Loch Striven sites only. It was not possible to make a meaningful comparison of results between these two sites as only three mussel samples were taken from the Loch Striven site, and these were all taken on the same occasion, an occasion on which the Troustan site was not sampled. The geometric mean *E. coli* result was higher for Pacific oysters taken from the Loch Striven site than mussels taken from the Troustan site, and more results over 4600 were recorded in oysters from the Loch Striven site. During the shoreline survey the oyster sample from the raft contained 310 *E. coli* / 100 g MPN while the mussel sample taken from the same site contained 1300 *E. coli* / 100 g MPN. It should be noted that the oysters were grown at depth while the mussels samples were taken from nearer the surface. However, there is some evidence to suggest that common mussels accumulate greater concentrations of faecal indicator bacteria than do Pacific oysters (Berry and Younger 2009) so this difference may be due to a combination of variation in contamination levels with depth and natural differences in accumulation between species.

Within the Troustan site, several locations were sampled and it appeared that prior to 21/03/2007 all results were reported against the nominal RMP rather than the actual sampling location which makes any spatial assessment of results prior to this date impossible. Samples submitted during 2007 came from the southern end of the shellfish farm while those submitted during 2008-09 came from the northern end. Assessment of these indicated that there was no significant difference in mean results between the two which suggests they are subject to similar sources of pollution. The highest result obtained came from the northern end of the site, though it is not clear whether this was due to a spatial or temporal effect. The nearest potential point source of contamination is an overboard toilet discharge on the barge used to service the site, which is moved around the farm as it is needed and so is equally likely to affect any part of the site if in use. No obvious overall temporal trends were seen during the course of the classification monitoring history, aside from possible peaks in results in mid 2004 and early 2007 at the Troustan site. The reason for this is not clear.

Seawater samples taken during the shoreline survey generally had levels of *E. coli* consistent with class B waters, ranging from 10 to 88 cfu/100ml, with two exceptions. 380 *E. coli* cfu/100ml were found in a seawater sample taken at the Troustan mussel lines, although there was no obvious reason for this higher result aside from possibly gulls seen in the area. >10000 *E. coli* cfu/100ml were found in a seawater sample taken adjacent to an actively discharging sewer pipe on the east shore.

During the shoreline survey, mussel samples taken from the Fearna site contained from 110 to 1700 *E. coli* MPN/100g. Mussel samples taken from the Troustan site contained from 50 to 1100 *E. coli* MPN/100g. Therefore, at the time of survey the Troustan site was slightly more contaminated, and this is the only direct comparison available of levels of *E. coli* in shellfish at these two sites. The samples from near the surface tended to be more highly contaminated than those taken at depth. This suggests the RMP should be set near the surface to capture the higher levels of contamination here.

Overall Conclusions

Despite being over 3 km from each other, the Troustan and Fearna sites are subject to similar local sources of contamination, i.e. mainly small streams draining areas of forest and rough grassland, although the Troustan site may be more heavily impacted by livestock, and the Fearna site may be more heavily impacted by contamination from eider ducks during the winter and spring, and by pheasants in the summer and autumn.

Overall, there was no strong evidence to support the separate classification of these two sites.

Contamination sources appear to be relatively similar between the two active mussel farms at Loch Striven and bacteriological results do not indicate any clear correlations between environmental factors and *E. coli* concentrations found in the shellfish. Higher levels of contamination were observed during the warmer months in summer and autumn and a weak correlation was found between *E. coli* levels in mussels and the reported water temperature.

The nearest potential point source of human sewage is the toilet on the barge used to service the farm, however this is easily remedied and once alternative arrangements are made the impact from other potential sources may become clearer.

Other sources of faecal contamination in the area include diffuse sources carried via rivers and streams to the loch. Some stratification was observed with surface water showing lower salinity than the water at depth, so faecal contaminants carried via freshwater sources are most likely to affect mussels near the surface. As no correlation was found with rainfall, these are unlikely to be the primary source of high episodes of faecal contamination found at the Troustan site.

As there is no history of monitoring at Fearna, the shoreline survey was the only source of information regarding contamination levels there. Water and shellfish samples taken during the shoreline survey showed that levels of contamination were higher near the shore at Fearna and roughly similar to those observed at Troustan. This indicates that the burns at the head of the loch are unlikely to be the primary source of contamination at the mussel farms though they may contribute to background levels within the loch.

There were potential sources south of the fishery, including the settlement of Inverchoalain and the raft of mothballed container ships, that could potentially affect water quality at the Troustan site. However, these sources are less likely to affect the fishery than others in closer proximity.

Within the Troustan site, there is some evidence from the shoreline survey, the distribution of livestock, and possibly the historical *E. coli* monitoring results that contamination is higher at the south of the site. Shoreline survey sampling results indicate higher contamination towards the surface of the lines, and some stratification was observed.

17. Recommendations

The Loch Striven oyster raft is not in commercial production, so does not require classification.

Overall, there is no strong evidence to support the separate classification of the two mussel sites at Troustan and Fearna. However, there is evidence to suggest that contamination levels may be higher at the head of the loch.

Therefore it is recommended that the production area boundaries be redefined as the area within lines drawn between NS 0543 8118 and NS 0602 8118, and between NS 0758 7600 and NS 0881 7600. This moves the northern boundary of the area south to exclude the Loch Striven oyster raft, and to prevent expansion towards the head of the loch where the Balliemore Burn discharges. It also moves the southern boundary to north of the rafted container ships.

It is recommended that the RMP be set at NS 0733 7686, where a dedicated sampling bag could be installed. Only stock of a harvestable size should be sampled. Samples should be taken from within 1m of the surface to capture any contamination in the surface layer following heavy rainfall. A sampling tolerance of 20 m is recommended to allow for movement of the mussel lines.

As seasonal fluctuations in historic *E. coli* monitoring results have been found, the sampling frequency should remain monthly.

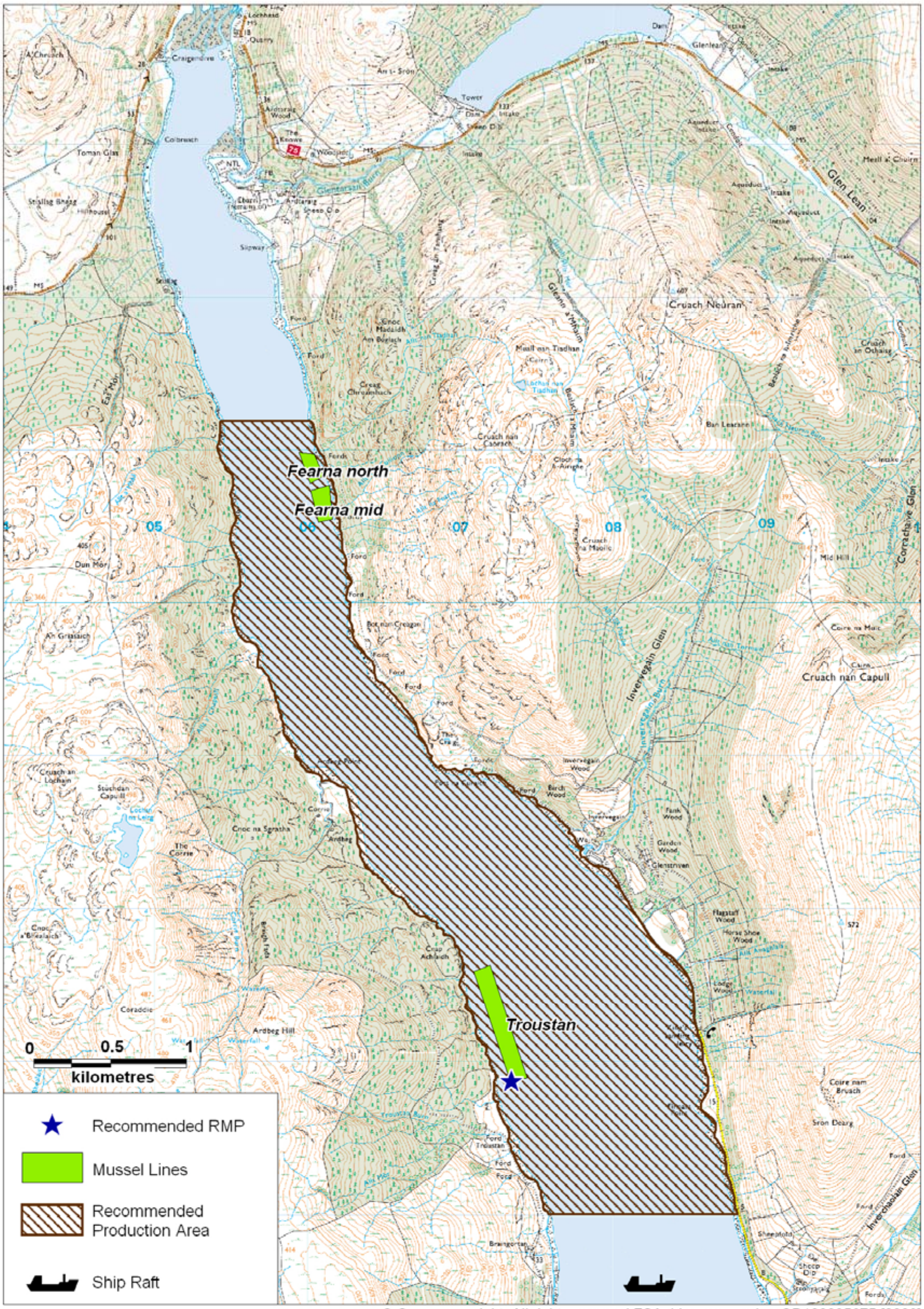


Figure 17.1 Recommendations for Loch Striven

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Sampling Plan for Loch Striven

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch Striven	Troustan, Fearna	AB 205 063 08	Common mussel	Rope	NS 0733 7686	207330	676860	20	<1	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Loch Striven	Common mussel	AB 205	Area bounded by lines drawn between NS 0493 8280 and NS 0541 8280 and between NS 0761 7550 and NS 0900 7550	NS 072 772	Area bounded by lines drawn between NS 0543 8118 and NS 0602 8118, and between NS 0748 7600 and NS 0881 7600	NS 0733 7686	Northern boundary moved to the south to exclude the oyster raft and to move it further away from Balliemore Burn. RMP moved to the southern end of the Troustan site.

Geology and Soils Information

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

References

Macaulay Institute. http://www.macaulay.ac.uk/explorescotland. Accessed September 2007.

General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

Both bacterial and viral pathogens affecting humans and livestock have been found in wild and captive seals. *Salmonella* and *Campylobacter* spp., some of which were antibiotic-resistant, were isolated from juvenile Northern elephant seals (*Mirounga angustirostris*) with *Salmonella* found in 36.9% of animals stranded on the California coast (Stoddard et al 2005). *Salmonella* and *Campylobacter* are both enteric pathogens that can cause acute illness in humans and it is postulated that the elephant seals were picking up resistant bacteria from exposure to human sewage waste.

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales. Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

Table 1 Cetacean sightings in 2007 – Western Scotland.

Common name	**Scientific name**	**No. sighted***
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28 x 10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77 x 10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Otters

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

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Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	150	1.9×10^9

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical data

All *E. coli* data was log transformed prior to statistical tests.

Section 11.5 One way ANOVA comparison of *E. coli* results by season (mussels)

```
Source  DF      SS     MS     F      P
season   3   4.750  1.583  3.72  0.016
Error   66  28.083  0.425
Total   69  32.833

S = 0.6523   R-Sq = 14.47%   R-Sq(adj) = 10.58%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      17  1.6632  0.4475  (---------*--------)
2      18  2.3494  0.8253                      (--------*--------)
3      20  2.1297  0.6252                 (-------*-------)
4      15  1.8577  0.6477       (---------*---------)
                           --+---------+---------+---------+-------
                           1.40      1.75      2.10      2.45

Pooled StDev = 0.6523


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of season

Individual confidence level = 98.96%


season = 1 subtracted from:

season    Lower  Center   Upper  --------+---------+---------+---------+-
2        0.1043  0.6861  1.2680                      (--------*---------)
3       -0.1011  0.4665  1.0340                  (---------*--------)
4       -0.4150  0.1945  0.8039             (---------*---------)
                                 --------+---------+---------+---------+-
                                     -0.60      0.00      0.60      1.20


season = 2 subtracted from:

season    Lower   Center   Upper  --------+---------+---------+---------+-
3       -0.7786  -0.2197  0.3393      (--------*---------)
4       -1.0931  -0.4917  0.1098  (---------*---------)
                                  --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.20


season = 3 subtracted from:

season    Lower   Center   Upper  --------+---------+---------+---------+-
4       -0.8596  -0.2720  0.3157     (--------*---------)
                                  --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.20
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (oysters)

```
Source  DF      SS     MS     F      P
season   3   8.528  2.843  4.88  0.013
```

```
Error   17   9.910  0.583
Total   20  18.438

S = 0.7635   R-Sq = 46.25%   R-Sq(adj) = 36.77%


                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev    +---------+---------+---------+---------
1      6  1.4630  0.7325    (-------*--------)
2      7  3.0215  0.8408                        (-------*------)
3      5  2.6140  0.8545                  (--------*--------)
4      3  2.0302  0.1798        (----------*-----------)
                            +---------+---------+---------+---------
                          0.80      1.60      2.40      3.20

Pooled StDev = 0.7635


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of season

Individual confidence level = 98.88%


season = 1 subtracted from:

season    Lower  Center   Upper  -------+---------+---------+---------+--
2        0.3510  1.5584  2.7659                    (-------*-------)
3       -0.1632  1.1510  2.4652                 (--------*-------)
4       -0.9675  0.5672  2.1018            (---------*---------)
                                 -------+---------+---------+---------+--
                                     -1.5       0.0       1.5       3.0


season = 2 subtracted from:

season    Lower   Center   Upper  -------+---------+---------+---------+--
3       -1.6783  -0.4075  0.8633        (-------*--------)
4       -2.4889  -0.9913  0.5064  (---------*---------)
                                  -------+---------+---------+---------+--
                                      -1.5       0.0       1.5       3.0


season = 3 subtracted from:

season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -2.1688  -0.5838  1.0012     (---------*----------)
                                  -------+---------+---------+---------+--
                                      -1.5       0.0       1.5       3.0
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (mussels)

```
Pearson correlation of logresult for rain ranked and 2 day rain ranked = 0.067
P-Value = 0.608
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (oysters)

```
Pearson correlation of logres rain ranked and 2 day rain ranked = 0.311
P-Value = 0.260
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (mussels)

```
Pearson correlation of logresult for rain ranked and 7 day rain ranked = 0.079
P-Value = 0.544
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (oysters)

```
Pearson correlation of logres rain ranked and 7 day rain ranked = 0.279
P-Value = 0.314
```

Section 11.6.2 Regression analysis – *E. coli* result vs tide height (mussels)

```
The regression equation is
Logresult = 0.06 + 0.615 tide height


Predictor      Coef  SE Coef     T      P
Constant      0.064    1.276  0.05  0.960
tide height  0.6155   0.4018  1.53  0.130


S = 0.683181   R-Sq = 3.3%   R-Sq(adj) = 1.9%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.0951  1.0951  2.35  0.130
Residual Error  68  31.7380  0.4667
Total           69  32.8331


Unusual Observations

       tide
Obs  height  Logresult     Fit  SE Fit  Residual  St Resid
 46    3.30     3.5441  2.0955  0.0972    1.4486     2.14R
 66    3.00     3.3802  1.9109  0.1061    1.4693     2.18R
 67    2.90     4.2041  1.8493  0.1353    2.3548     3.52R

R denotes an observation with a large standardized residual.
```

Section 11.6.2 Regression analysis – *E. coli* result vs tide height (oysters)

```
The regression equation is
Logresult = - 4.61 + 2.16 tide height


Predictor      Coef  SE Coef      T      P
Constant     -4.611    2.757  -1.67  0.111
tide height  2.1554   0.8531   2.53  0.021


S = 0.852288   R-Sq = 25.1%   R-Sq(adj) = 21.2%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   4.6368  4.6368  6.38  0.021
Residual Error  19  13.8015  0.7264
```

```
Total           20  18.4383


Unusual Observations

       tide
Obs  height  Logresult    Fit  SE Fit  Residual  St Resid
 20    3.10      3.959  2.071   0.214     1.888      2.29R

R denotes an observation with a large standardized residual.
```

Section 11.6.2 Circular linear correlation for tidal state and *E. coli* result (mussels)

CIRCULAR-LINEAR CORRELATION

Analysis begun: 30 October 2008 11:48:50

Variables (& observations)	r	p
Angles & Linear (70)	0.114	0.418

Section 11.6.2 Circular linear correlation for tidal state and *E. coli* result (oysters)

CIRCULAR-LINEAR CORRELATION

Analysis begun: 30 October 2008 11:55:19

Variables (& observations)	r	p
Angles & Linear (21)	0.145	0.687

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (mussels)

```
The regression equation is
logresult for water temp = 1.27 + 0.0675 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    1.2685   0.3034  4.18  0.000
WaterTemp  0.06754  0.02651  2.55  0.013


S = 0.670016   R-Sq = 9.9%   R-Sq(adj) = 8.4%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.9135  2.9135  6.49  0.013
Residual Error  59  26.4863  0.4489
Total           60  29.3998


Unusual Observations

                logresult
                for water
Obs  WaterTemp       temp     Fit  SE Fit  Residual  St Resid
 39       13.0     3.5441  2.1465  0.1012    1.3975      2.11R
 51        2.0     1.9542  1.4036  0.2529    0.5506      0.89 X
 58       15.0     4.2041  2.2816  0.1369    1.9225      2.93R
```

```
R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (oysters)

```
The regression equation is
logresult for water temp = 0.254 + 0.176 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    0.2541   0.5573  0.46  0.655
WaterTemp  0.17579  0.04272  4.12  0.001


S = 0.659330   R-Sq = 51.4%   R-Sq(adj) = 48.4%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   7.3619  7.3619  16.93  0.001
Residual Error  16   6.9555  0.4347
Total           17  14.3174
```

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 30 October 2008 12:38:06

Variables (& observations)	r	p
Angles & Linear (55)	0.243	0.047

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (oysters)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 30 October 2008 12:45:28

Variables (& observations)	r	p
Angles & Linear (13)	0.316	0.366

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (mussels)

```
The regression equation is
logresult for salinity = 2.33 - 0.0114 Salinity


Predictor      Coef  SE Coef      T      P
Constant     2.3267   0.4143   5.62  0.000
Salinity   -0.01142  0.01497  -0.76  0.449


S = 0.615766   R-Sq = 1.0%   R-Sq(adj) = 0.0%


Analysis of Variance
```

```
Source          DF       SS      MS     F      P
Regression       1   0.2206  0.2206  0.58  0.449
Residual Error  55  20.8542  0.3792
Total           56  21.0748


Unusual Observations

               logresult
                     for
Obs  Salinity   salinity     Fit  SE Fit  Residual  St Resid
 36      26.0     3.5441  2.0298  0.0833    1.5142     2.48R
 56       2.0     2.4914  2.3038  0.3850    0.1875     0.39 X
 57       0.0     1.6021  2.3267  0.4143   -0.7246    -1.59 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (oysters)

```
The regression equation is
logresult for salinity = 2.16 - 0.0052 Salinity


Predictor      Coef  SE Coef      T      P
Constant     2.1618   0.3806   5.68  0.000
Salinity   -0.00524  0.02846  -0.18  0.857


S = 0.945489   R-Sq = 0.3%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0304  0.0304  0.03  0.857
Residual Error  12  10.7274  0.8939
Total           13  10.7578
```

Section 12 One way ANOVA comparison of SEPA sampling results by quarter at NS 09400 72400

```
Source   DF      SS     MS     F      P
Quarter   3   9.899  3.300  6.44  0.009
Error    11   5.636  0.512
Total    14  15.534

S = 0.7158   R-Sq = 63.72%   R-Sq(adj) = 53.83%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---------+---------+---------+---------+
Q1     4  2.0998  0.4295    (-------*-------)
Q2     3  2.4263  0.7273      (--------*--------)
Q3     4  3.9208  0.9609                      (-------*-------)
Q4     4  1.9237  0.6466  (-------*-------)
                          ---------+---------+---------+---------+
                                 2.0       3.0       4.0       5.0

Pooled StDev = 0.7158


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Quarter
```

```
Individual confidence level = 98.82%


Quarter = Q1 subtracted from:

Quarter    Lower   Center   Upper  --------+---------+---------+---------+-
Q2       -1.3203   0.3264  1.9732            (--------*-------)
Q3        0.2964   1.8210  3.3456                    (-------*-------)
Q4       -1.7008  -0.1762  1.3484          (-------*-------)
                                   --------+---------+---------+---------+-
                                        -2.0       0.0       2.0       4.0


Quarter = Q2 subtracted from:

Quarter    Lower   Center   Upper  --------+---------+---------+---------+-
Q3       -0.1522   1.4945  3.1413                  (-------*--------)
Q4       -2.1494  -0.5026  1.1442        (-------*--------)
                                   --------+---------+---------+---------+-
                                        -2.0       0.0       2.0       4.0


Quarter = Q3 subtracted from:

Quarter    Lower   Center    Upper  --------+---------+---------+---------+-
Q4       -3.5217  -1.9971  -0.4725  (-------*-------)
                                    --------+---------+---------+---------+-
                                         -2.0       0.0       2.0       4.0
```

Section 15 Pearsons' correlation of *E. coli* levels in seawater and salinity

```
Pearson correlation of logresult and salinity g/L = -0.168
P-Value = 0.621
```

Hydrographic Methods

1.0 Introduction

This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

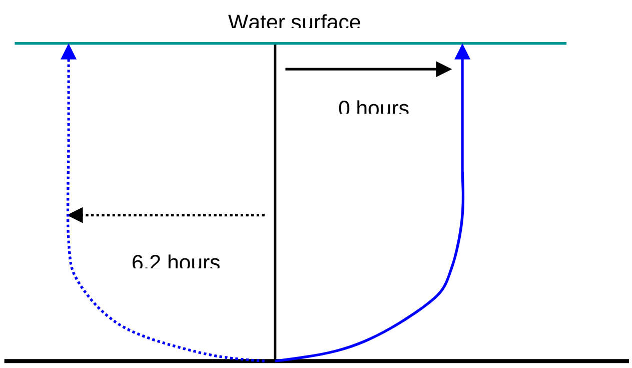
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

1.1 Background processes

This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

a)



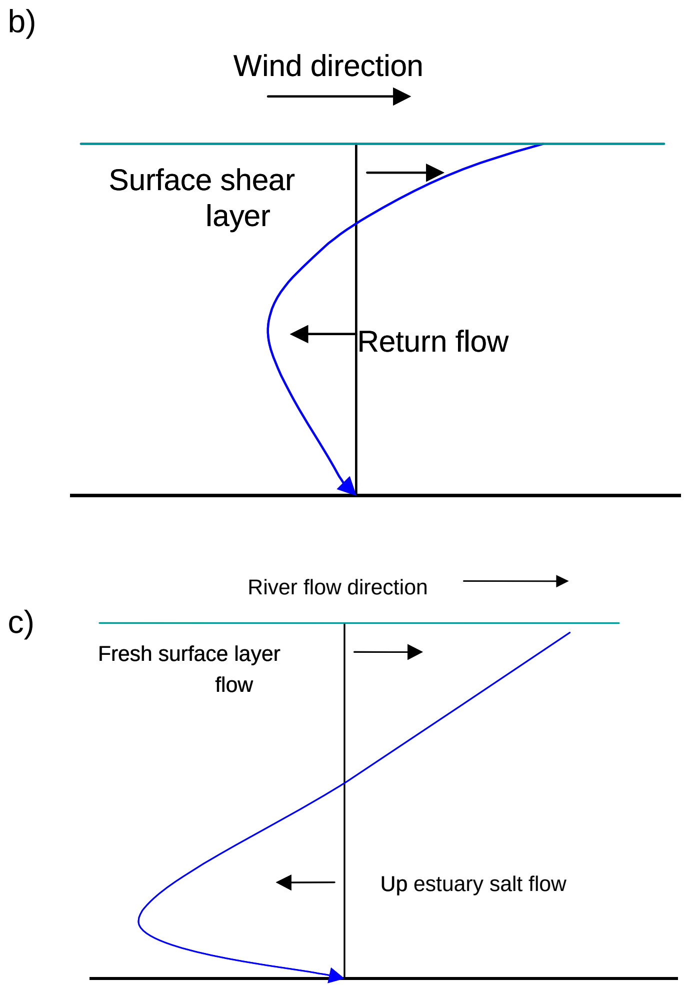


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

In sea lochs, mechanisms such as “wind rows” can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

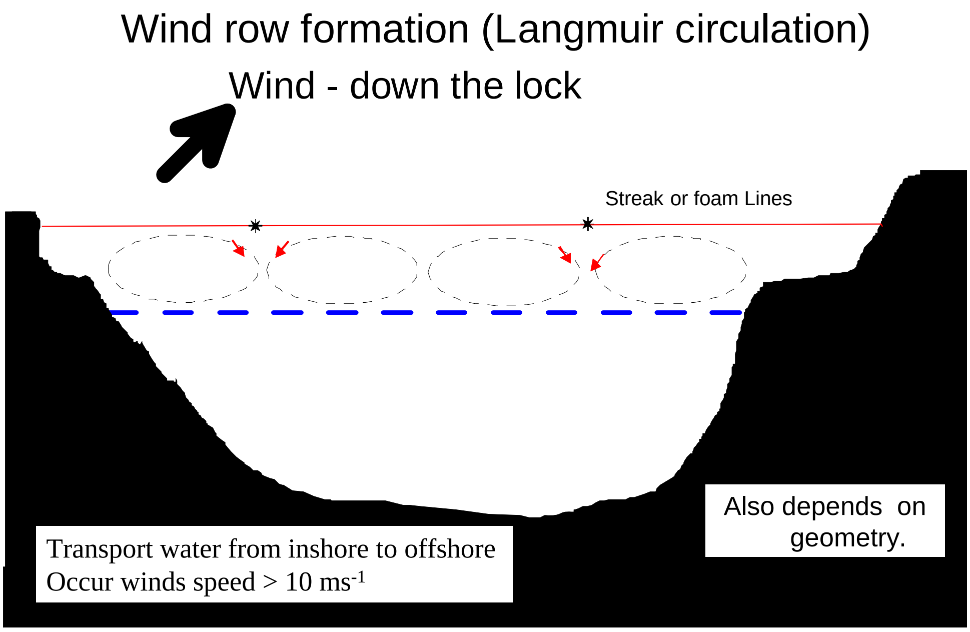


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

2.0 Basic Assessment

This will be applied to most sites and consists of a description of bathymetry and the tidal regime obtained from admiralty charts and tidal diamonds and is not described in detail here. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.
7. Estimates of flow speed combined with T_{90} will give a 'region of influence'.
8. The ratio of river run-off to tidal prism gives an indication of the importance of density effects.

Many Scottish shell fish production areas occur within sea lochs. These are fjord like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

For the more detailed assessment of sea loch regions, the “Sea Loch catalogue” produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends, on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

Dilution calculations in regions with steep and variable bathymetry typical of sea lochs are extremely difficult. The following methods are applied.

For class A and B classifications, correlation data (European Commission 1996) suggest the following water concentration need to be achieved:

Class A: 1 *E. coli* per 100 ml = 10^4 m^{-3}
Class B: 100 *E. coli* per 100 ml = 10^6 m^{-3}

3.0 References

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

4.0 Glossary

The following technical terms appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.
Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.

Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

Shoreline Survey Report

Loch Striven
AB 205

Scottish Sanitary Survey Project

Scottish Sanitary Survey Project Cefas

Prod. area:	Loch Striven
Site name:	Troustan (AB 205 063)
	Fearna (AB 205 062)
Species:	Common mussels
Harvesters:	Jim McLachlan – Loch Striven Mussels
	Mr. McGhie – oyster raft at head of loch
Local Authority:	Argyll & Bute Council
Status:	Classified fishery (mussels only)

Date Surveyed:	14-15 October 2008
Surveyed by:	Michelle Price-Hayward, Christine McLachlan
Existing RMP:	NS 072 772
Area Surveyed:	See Map in Figure 1

Weather observations
14/10/08 Mostly overcast, some light rain but mostly dry. Winds calm (force 1). Temp 12C.

Site Observations

Fishery
The Loch Striven production area currently consists of two farmed sites: Troustan and Fearna. Troustan lies along the western shore of the loch, toward the southern end of the current production area. Fearna lies along the eastern shore approximately 2 km north of Troustan.

Both sites have longlines with a system of continuous rope ladders strung in loops to a depth of 8 metres along the long lines. Harvest is rotational within the sites and 10 of the long lines are typically harvested from each site each year.

Currently, Fearna has two blocks consisting of 10 long lines each, with a third block due to be deployed in the near future. Troustan has 3 blocks of 10 long lines each. Troustan also has antipredator netting in place awaiting deployment. This is to protect the lines from Eider ducks, which are reported to be present between November and May, at times numbering in the thousands.

Harvesting typically takes place between November and May. No harvesting is undertaken between July and November due environmental and market factors.

The lines are harvested using a specially adapted barge and the rope ladders are drawn through a brush lined opening to remove the mussels without raising the ladders clear of the water. Stripped mussels go into a tank from which they are then graded and sorted.

A further lease area is located at the northern end of the production area and has historically been farmed by a Mr. McGhie, who has a raft in place on which mussels and oysters were farmed. This was in reasonable condition and had bags of oysters suspended from ropes beneath the raft (Figures 4-6). The harvester later stated that these were not intended for commercial sale.

Sewage/Faecal Sources

There were no community septic tanks or discharges observed during the survey. Several private homes were observed, all of which would be on septic tanks. One of the workmen on the shellfish farm indicated that there were only 4 permanent residents at the Glenstriven Estate. One discharge pipe was observed actively discharging below water at the Keeper's Cottage and a seawater sample taken from adjacent to the discharge contained greater than 10000 *E. coli*/ 100ml, confirming that it was a foul discharge.

A further discharge pipe was observed adjacent to a small cottage further north along the shoreline from the Keeper's Cottage.

There was a toilet on the service raft at the Troustan mussel farm. This discharged directly to the water below the raft. The raft is moved around the farm as work is undertaken and so this represents a non-fixed point source that would be located on or very near the shellfish lines.

Seasonal Population

Some of the cottages on the estates are let to summer visitors, but it is the autumn hunting season that sees the highest number of visitors to this area. Even so, local information indicated that generally no more than 15-20 hunters would be expected any given weekend during the season.

Boats/Shipping

A ship was observed further south in the loch, at the MOD pier. A small fishing boat was observed on a mooring off the Keepers Cottage on the Glenstriven Estate.

Two small workboats, a harvesting raft and a service raft were associated with the mussel farms.

Land Use

Land use in the area is predominantly forestry with some grazing. 20 cattle were observed in a pasture on the western side of the loch near Troustan. At the head of the loch, 29 sheep were observed grazing on pasture adjacent to the burn. Sheep were also observed on the Ardtaraig Estate. The Glenstriven Estate hosts hunting parties in the autumn and pheasants numbering in the hundreds were observed in most open areas around the loch.

Some of the forested area is plantation, though no areas of recent clear cutting were observed.

Wildlife/Birds

The harvester has reported that eider ducks were present, sometimes in large numbers, on the farm. Anti predator netting was set up around the Troustan mussel farm and the harvester indicated that this would also be installed at Fearna at some point in the future.

One seal was observed lying across the lines at Troustan. Gulls and cormorants were observed resting on the floats, in numbers >100. Herons, oystercatchers and swans were also observed around the loch, but none in large concentrations.

Figure 1. Map of Shoreline Observations

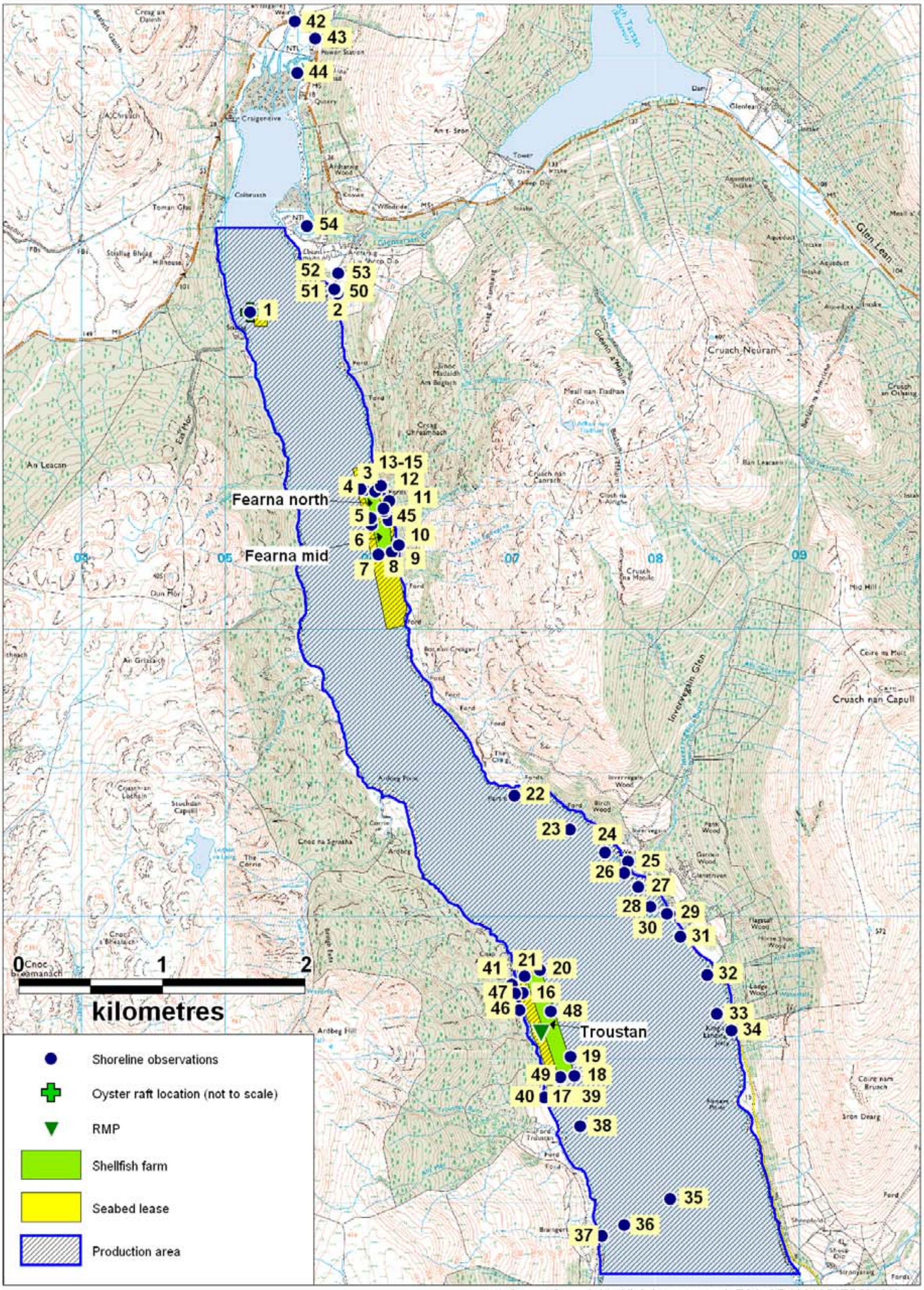


Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Description
1	14/10/2008	9:58	NS 05172 82217	205172	682217	Figures 4,5,6	Mussel raft of 16 cross beams with multiple droppers off each. Oyster bags at ends of lines. Shellfish sample 1(oyster), Shellfish sample 2 (mussel), Water sample 1. Salinity profile 1. Water flow at surface observed moving down-loch, measured at 0.036 m/s.
2	14/10/2008	10:28	NS 05767 82338	205767	682338	Figure 7	Slipway and disused depuration shed. Stream flowing through pipe adjacent slipway (sampled on 15/10). Land cover deciduous wood at lower elevations, coniferous higher on East side, west side mostly coniferous with rock and short vegetation above.
3	14/10/2008	10:42	NS 05969 80975	205969	680975		Fearna, two blocks of 10 lines each, with rope ladders looped along either side of floats to 8 meters depth. A third block to be added soon at south end. Shellfish samples 3 (near surface), 4 (mid-depth), and 5 (bottom) taken from the rope ladders. Water sample 2. Salinity profile 2. Queen scallops found on line. Flow at surface moving down-loch at 0.059 m/s. Halocline visually evident.
4	14/10/2008	11:05	NS 05944 80984	205944	680984	Figure 8	Corner of Fearna North mussel lines.
5	14/10/2008	11:07	NS 06014 80781	206014	680781	Figure 9	Corner of Fearna North mussel lines.
6	14/10/2008	11:08	NS 06019 80734	206019	680734		Corner of Fearna South mussel lines.
7	14/10/2008	11:11	NS 06067 80525	206067	680525	Figure 10	Corner of Fearna South mussel lines. Eastern shoreline here predominanly deciduous woodland with patches of coniferous plantation.
8	14/10/2008	11:12	NS 06159 80546	206159	680546		Corner of Fearna South mussel lines.
9	14/10/2008	11:16	NS 06209 80595	206209	680595		Stream 1.25 m wide x 0.11 m deep x 0.08 m/s. Water sample 3. Pheasant observed near stream.
10	14/10/2008	11:28	NS 06140 80766	206140	680766		Corner of Fearna South mussel lines. Raft used for installation of lines moored appr. 20 m off this mark. New lines in place, floating on water surface.
11	14/10/2008	11:29	NS 06105 80830	206105	680830		Corner of Fearna North mussel lines.
12	14/10/2008	11:34	NS 06143 80898	206143	680898		Stream 1.04 m wide x 0.19 m deep x 0.11 m/s. Water sample 4.
13	14/10/2008	11:40	NS 06043 80969	206043	680969		Corner of Fearna North mussel lines.
14	14/10/2008		NS 06043 80969	206043	680969		No specific observation.
15	14/10/2008	11:43	NS 06087 81005	206087	681005		Stream 1.07 m wide x 0.16 m deep x 0.057 m/s. Water sample 5.

No.	Date	Time	NGR	East	North	Associated photograph	Description
16	14/10/2008	12:04	NS 07075 77467	207075	677467	Figures 11, 12, 13	Service barge that is moved around the farm. Has sheds for storage and a toilet that is flushed using a bucket of seawater and discharges directly below the raft. A scum was observed on the water inshore of the barge. There was also a sheen of oil on the water coming from the barge. Water sample 6.
17	14/10/2008	12:40	NS 07328 76859	207328	676859	Figures 14,15,16	Corner of Troustan mussel lines. Two further work barges in view on farm. Current moving up the loch here. >100 gulls and cormorants roosting on floats around the farm.
18	14/10/2008	12:42	NS 07434 76890	207434	676890		Corner of Troustan mussel lines.
19	14/10/2008	12:43	NS 07405 77023	207405	677023		Seal basking on lines.
20	14/10/2008	12:45	NS 07193 77629	207193	677629		Corner of Troustan mussel lines.
21	14/10/2008	12:46	NS 07086 77585	207086	677585		Corner of Troustan mussel lines.
22	14/10/2008	12:52	NS 07016 78846	207016	678846		House, unoccupied, white drain pipe leading underground. 20 pheasants. Small stream, not measured.
23	14/10/2008	12:58	NS 07404 78609	207404	678609		15 oyster catchers on shore.
24	14/10/2008	12:59	NS 07648 78449	207648	678449		Large white house, mooring buoys. 35 pheasants. Large burn.
25	14/10/2008	13:07	NS 07807 78385	207807	678385	Figure 17	Burn, 7.70 m x 0.21 m x 0.117 m/s. Water sample 7. Glen Striven Estate, 6 houses and holiday cottages, 4 year round residents (2 adults, 2 children).
26	14/10/2008	13:22	NS 07779 78305	207779	678305	Figure 18	Holiday cottage, no apparent pipe to shore. Palm tree next to cottage (mature - indicative of microclimate?).
27	14/10/2008	13:25	NS 07878 78208	207878	678208		Sheds and slipway.
28	14/10/2008	13:27	NS 07964 78071	207964	678071	Figures 19, 20	Boat on mooring, house with pier. Very small house adjacent with pipe leading to shore.
29	14/10/2008	13:31	NS 08095 78021	208095	678021	Figure 21	Discharge pipe running under gravel on shore (see photos).
30	14/10/2008	13:35	NS 08081 78021	208081	678021		Water sample 8, seawater from near where pipe goes under shore.
31	14/10/2008	13:39	NS 08171 77860	208171	677860		House set back from shore, stream and pine plantation up hill.
32	14/10/2008	13:42	NS 08360 77591	208360	677591		2 swans and a cormorant.
33	14/10/2008	13:42	NS 08427 77323	208427	677323	Figure 22	Area of scum on water surface, similar to that seen near work service barge (waypoint 215). Mooring with boat on it.Discharge pipe across shore.
34	14/10/2008	13:46	NS 08529 77206	208529	677206		End of discharge pipe (underwater), grey discharge cloud apparent. Water sample 9.
35	14/10/2008	13:52	NS 08103 76030	208103	676030		Water sample 10, salinity profile 3. 20 Cattle grazing on west shore. These only here for a month or two each autumn.
36	14/10/2008	14:06	NS 07781 75847	207781	675847	Figure 23	Large house with no apparent discharge pipes.
37	14/10/2008	14:10	NS 07626 75774	207626	675774		Water sample 11, seawater.

No.	Date	Time	NGR	East	North	Associated photograph	Description
38	14/10/2008	14:13	NS 07474 76539	207474	676539		12 sheep near shoreline.
39	14/10/2008	14:15	NS 07323 76874	207323	676874		Salinity profile 4. Water sample 12.
40	14/10/2008	14:29	NS 07223 76737	207223	676737		Stream 0.95 m x 0.08 m x 0.156 m/s. Water sample 13. Deer faeces observed near stream. No algae on rocks.
41	14/10/2008	14:43	NS 06998 77526	206998	677526		Stream 1.1 m x 0.15 m x 0.011 m/s. Water sample 14.
42	14/10/2008	15:54	NS 05485 84247	205485	684247	Figure 24	Burn, 7.6 m x 0.425 m x 0.473 m/s. Water sample 15. 20 sheep on pasture east of burn. 9 sheep south of road, west of burn.
43	14/10/2008	16:11	NS 05625 84125	205625	684125	Figure 25	Stream with pipes running across. 2.2 m x 0.09 m x 0.26 m/s. Water sample 16.
44	14/10/2008	16:30	NS 05503 83888	205503	683888		Burn discharging from Striven Power Station hydroelectric plant. Too deep and swift to measure safely. Water sample 17.
45	15/10/2008	10:00	NS 06102 80845	206102	680845		Shellfish sample 6 (near surface), 7 (mid depth) and 8 (bottom). Water sample 18. Salinity profile 5.
46	15/10/2008	10:20	NS 07050 77348	207050	677348	Figure 26	Stream, too small to sample directly. Water sample 19, taken from sea near discharge. Salinity 20 ppt.
47	15/10/2008	10:29	NS 07019 77464	207019	677464		Stream over rocks, too shallow to sample directly. Water sample 20 taken from sea at discharge.
48	15/10/2008	10:51	NS 07268 77340	207268	677340	Figure 27	Troustan mussel samples 9 (near surface), 10 (mid depth) and 11 (bottom). Water sample 21. Salinity profile 6. On this section there was no growth at the 8 metre depth (bottom of ladder) so sample was taken from deepest growth which was at 6 m.
49	15/10/2008	11:07	NS 07334 76881	207334	676881		Troustan mussel samples 12 (near surface), 13 (mid depth) and 14 (bottom). Water sample 22. Salinity profile 7.
50	15/10/2008	11:58	NS 05781 82348	205781	682348	Figures 28, 29	Stream through pipe adjacent to slipway at Ardtaraig. Inner pipe diameter, 30 cm. 17 cm width of wetted surface, 2 cm depth. Flow 1.7 l/s. Water sample 23.
51	15/10/2008	12:05	NS 05771 82368	205771	682368	Figure 30	Dry pipe, 30 cm diameter, black. Evidence of previous flow. Seal in water just offshore.
52	15/10/2008	12:09	NS 05760 82380	205760	682380	Figure 31	Cotton bud sticks in shoreline debris.
53	15/10/2008	12:19	NS 05788 82488	205788	682488	Figure 32	45 sheep plus over 100 pheasants in field.
54	15/10/2008	12:30	NS 05570 82820	205570	682820		Burn, 7.5 m x 0.26 m x 0.114 m/s. Water sample 24.

Photos referenced in the table can be found attached as Figures 5-11.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the voe or loch.

Sampling

Water and shellfish samples were collected at sites marked on the map. Samples were transferred to cool boxes for transport to the laboratory. All samples were analysed for *E. coli* content. Bacteriology results follow in Tables 2 and 3.

Water sampled on site was tested for salinity using a hand held refractometer. These readings are recorded in Table 1 as salinity in parts per thousand (ppt). Sample salinities were also tested by the laboratory using a salinity meter under more controlled conditions. These results are more precise than the field measurements and are shown in Table 2, given in units of grams salt per litre of water, which are equivalent to ppt. Salinity profiles were taken at various locations on site using a WTW salinity meter. Results are shown in Table 4.

Table 2. Water Sample Results

Sample No.	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (g/L)
1	NS 05172 82217	Seawater	24	28
2	NS 05969 80975	Seawater	28	27.8
3	NS 06209 80595	Freshwater	100	-
4	NS 06143 80898	Freshwater	<100	-
5	NS 06087 81005	Freshwater	<100	-
6	NS 07075 77467	Freshwater	<100	-
7	NS 07807 78385	Freshwater	100	-
8	NS 08081 78021	Seawater	14	27.8
9	NS 08529 77206	Seawater	>10000	25.8
10	NS 08103 76030	Seawater	15	25.4
11	NS 07626 75774	Seawater	21	22.9
12	NS 07323 76874	Seawater	10	25.1
13	NS 07223 76737	Freshwater	<100	-
14	NS 06998 77526	Freshwater	<100	-
15	NS 05485 84247	Freshwater	1100	-
16	NS 05625 84125	Freshwater	<100	-
17	NS 05503 83888	Freshwater	100	-
18	NS 06102 80845	Seawater	75	26.0
19	NS 07050 77348	Seawater	66	22.0
20	NS 07019 77464	Seawater	62	17.8
21	NS 07268 77340	Seawater	380	26.2
22	NS 07334 76881	Seawater	88	25.8
23	NS 05781 82348	Freshwater	3100	-
24	NS 05570 82820	Freshwater	34	-

Table 3. Shellfish Sample Results

Sample No.	Grid Ref	Type	*Estimated sampling depth*	E. coli (MPN/100g)
1	NS 05172 82217	Pacific Oyster		310
2	NS 05172 82217	Common Mussel		1300
3	NS 05969 80975	Common Mussel	Top	500
4	NS 05969 80975	Common Mussel	Middle	50
5	NS 05969 80975	Common Mussel	Bottom	310
6	NS 06102 80845	Common Mussel	Top	1100
7	NS 06102 80845	Common Mussel	Middle	220
8	NS 06102 80845	Common Mussel	Bottom	160
9	NS 07268 77340	Common Mussel	Top	1100
10	NS 07268 77340	Common Mussel	Middle	1700
11	NS 07268 77340	Common Mussel	Bottom	1100
12	NS 07334 76881	Common Mussel	Top	1300
13	NS 07334 76881	Common Mussel	Middle	110
14	NS 07334 76881	Common Mussel	Bottom	310

Table 4. Salinity Profiles

Profile	Date	Waypoint	Grid Ref	Easting	Northing	Depth (m)	Salinity (ppt)	Temp C
1	14/10/2008	1	NS 05172 82217	205172	682217	10	31.1	12.3
1	14/10/2008	1	NS 05172 82217	205172	682217	5	30.9	12.2
1	14/10/2008	1	NS 05172 82217	205172	682217	3	30.7	12.2
1	14/10/2008	1	NS 05172 82217	205172	682217	1	29.3	12.2
2	14/10/2008	3	NS 05969 80975	205969	680975	10	31.4	12.4
2	14/10/2008	3	NS 05969 80975	205969	680975	5	31	12.4
2	14/10/2008	3	NS 05969 80975	205969	680975	3	30.8	12.3
2	14/10/2008	3	NS 05969 80975	205969	680975	1	29.8	12.3
3	14/10/2008	35	NS 08103 76030	208103	676030	10	31.2	12.5
3	14/10/2008	35	NS 08103 76030	208103	676030	5	30.4	12.5
3	14/10/2008	35	NS 08103 76030	208103	676030	3	29.4	12.3
3	14/10/2008	35	NS 08103 76030	208103	676030	1	26.1	11.5
4	14/10/2008	39	NS 07323 76874	207323	676874	10	31.1	12.3
4	14/10/2008	39	NS 07323 76874	207323	676874	5	30.3	12.3
4	14/10/2008	39	NS 07323 76874	207323	676874	3	29.2	12.2
4	14/10/2008	39	NS 07323 76874	207323	676874	1	27.4	11.9
5	15/10/2008	45	NS 06102 80845	206102	680845	10	31.3	12.5
5	15/10/2008	45	NS 06102 80845	206102	680845	5	28.9	12.3
5	15/10/2008	45	NS 06102 80845	206102	680845	3	26.7	12
5	15/10/2008	45	NS 06102 80845	206102	680845	1	24.9	11.8
6	15/10/2008	48	NS 07268 77340	207268	677340	10	30.3	12.5
6	15/10/2008	48	NS 07268 77340	207268	677340	5	27.5	12.2
6	15/10/2008	48	NS 07268 77340	207268	677340	3	27	12.2
6	15/10/2008	48	NS 07268 77340	207268	677340	1	25.2	12
7	15/10/2008	49	NS 07334 76881	207334	676881	10	30.4	12.5
7	15/10/2008	49	NS 07334 76881	207334	676881	5	27.9	12.2
7	15/10/2008	49	NS 07334 76881	207334	676881	3	27	12.1
7	15/10/2008	49	NS 07334 76881	207334	676881	1	24.2	11.4

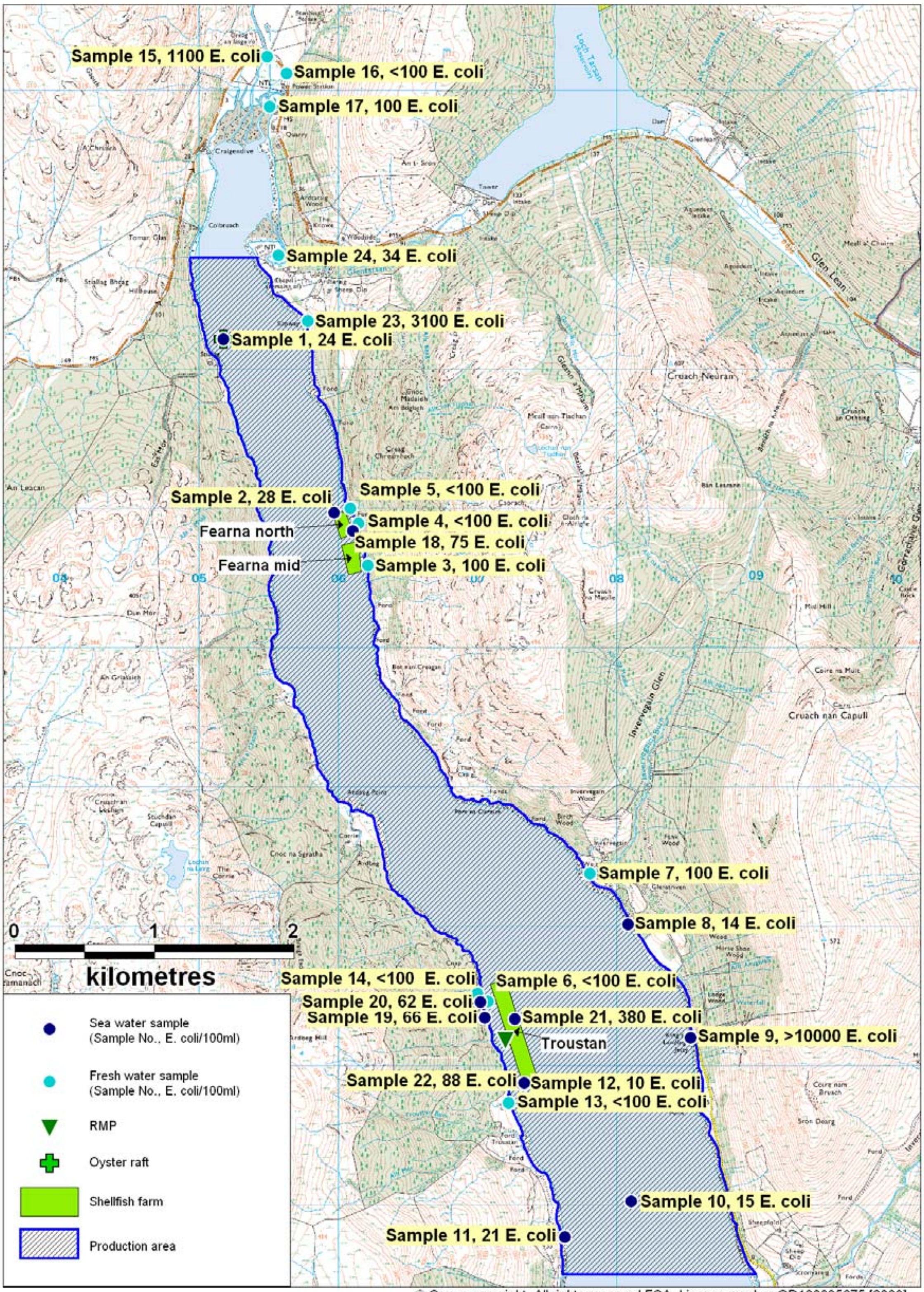


Figure 2. Water sample results map

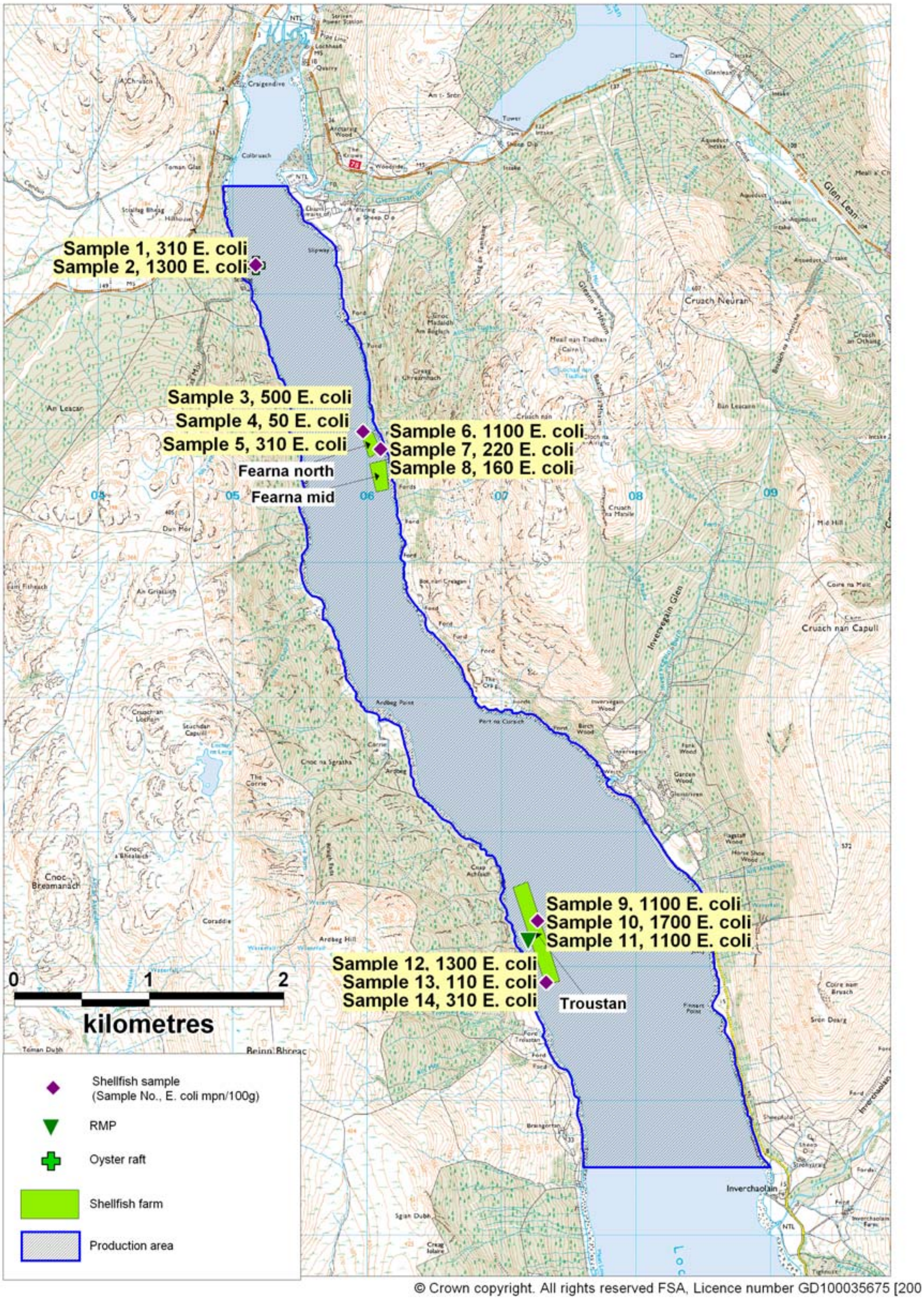


Figure 3. Shellfish sample results map

Photographs

Figure 4. Oyster bags on raft

Figure 5. Oyster raft 1

Figure 6. Oyster raft 2

Figure 7. Slipway and disused depuration shed

Figure 8. Fearna mussel lines

Figure 9. Fearna mussel lines

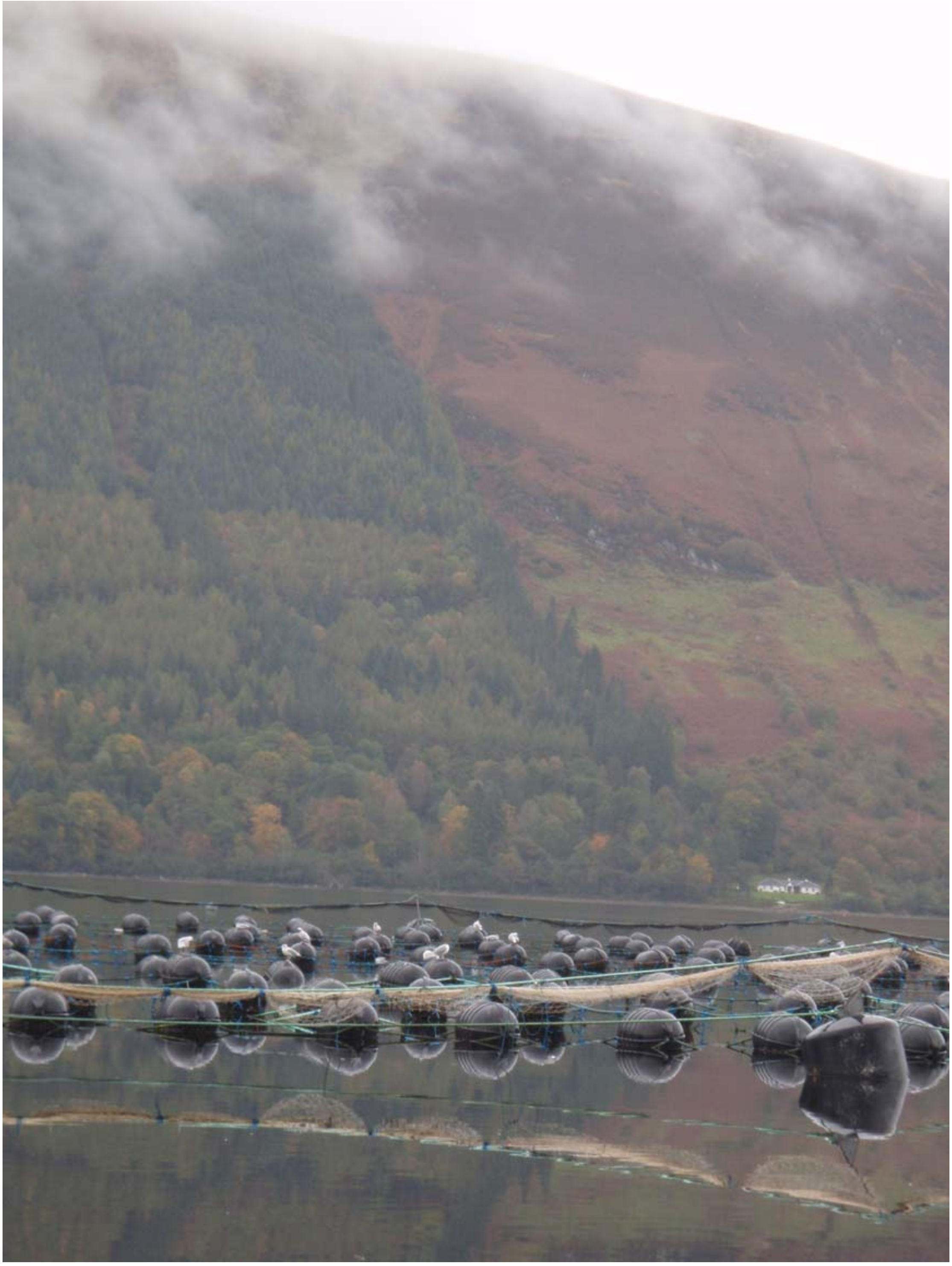


Figure 10. Eastern shoreline predominantly deciduous woodland with patches of coniferous plantation

Figure 11. Service barge

Figure 12. Scum observed on the water inshore of the barge

Figure 13. Shoreline south along from barge

Figure 14. Troustan mussel lines

Figure 15. Troustan mussel lines

Figure 16. Troustan mussel lines

Figure 17. Glen Striven Estate

Figure 18. Palm tree next to cottage

Figure 19. Boat on mooring

Figure 20. Small cottage with pipe leading to the shore

Figure 21. Discharge pipe running from small cottage

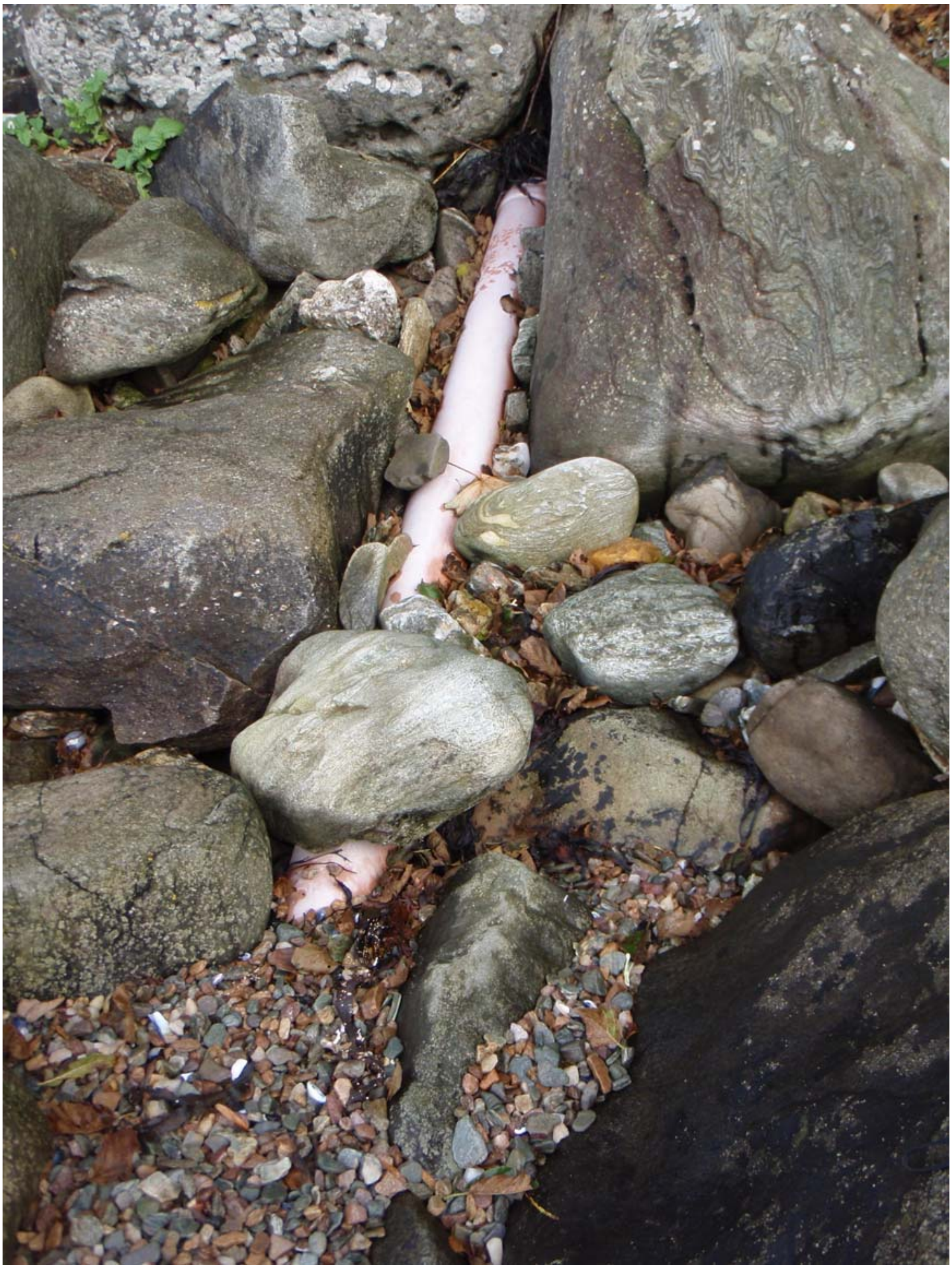


Figure 22. Discharge pipe across shore

Figure 23. Large house with no apparent discharge pipes

Figure 24. Measuring flow in large burn

Figure 25. Stream with pipes running across it.

Figure 26. Stream across rocks at Troustan

Figure 27. Mussel sampling

Figure 28. Stream through pipe adjacent to slipway at Ardtaraigh

Figure 29. Slipway at Ardtaraig

Figure 30. Dry pipe, evidence of previous flow

Figure 31. Cotton bud sticks in shoreline debris

Figure 32. Sheep at head of loch